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FOREWORD

Of late, contamination control has become a great headache not only for the electronics and precision instrument engineering, but also for the medical world and the pharmaceutical industry as well. Again, it has become the top priority issue in America since its space development program demands careful steps to ensure strict prevention ot contamination of the space.

Although the clean room technology has made relatively rapid progress during the last few years in Japan, yet it will take about ten years to catch up with America.

On receipt of an invitation from the AACC (American Association of Contamination Control) the Japan Air Cleaning Association sponsored a Mission for Studying Contamination Control to attend the annual technical conference of the AACC held on April 20, 1970 at Los Angeles, and at the same time study the present state of contamination control technology in America.

The Mission left Haneda on March 31, 1970 and carried out hurried investigation according to a preplanned schedule upto April 22, 1970. The present issue of the journal is devoted to the final report of the study. Although the authorities everywhere tried to be as cooperative as possible, yet the mission can be considered to be only a limited success since there were many points which had a direct bearing on the military affairs and company secrets, and as a consequence cameras were not allowed in most of the cases and many questions of vital nature elicited only evasive replies. Even then it is hoped that this report will prove to be useful to the people working in the field as this happens to be the latest report on the present line of thinking of the Americans on contamination control and clean room.

In the end, thanks are due to the members of the Mission who cooperated wholeheartedly in compiling this report.

Masaichi Fujii,
Leader of the
Mission for Studying Contamination Control
and Clean Room Sponsored by the Japan Air
Cleaning Association,

September 1970

2. LIST OF THE MEMBERS OF THE MISSION FOR STUDYING CONTAMINATION CONTROL AND CLEAN ROOM IN AMERICA

---

1. Fujii, Leader; Professor, Department of Architectural Engineering, Shibaura Kogyo University, 3-9-14, Shibaura, Minato-Ku. Tokyo, (452) 3201.

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MEMBERS OF THE MISSION

9. Nagashima, Member, Principal Scientific Officer, Nihon Garasu Seni K.K., 4902, Takazaya Komoricho, Tsu City, Mie Prefecture, 0592(84)2111.

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3. TRAVEL SCHEDULE OF THE MISSION

Date and Day	Place	Time	Transport	Remarks
1. March 31, Tuesday	Dep. Tokyo	20:05	CP 402	Boarded CP 70 after arriving at Vancouver by C. P. airliner
	Arr. Vancouver	12:00		
	Dep. Vancouver	14:00	CP 070	To Toronto by C. P. airliner
	Arr. Toronto	21:54		(Overnight stay)
2. April 1, Wednesday	Dep. Toronto	09:45	AC 782	After reaching New York by Air Canada, boarded Eastern Airlines for Aurland
	Arr. New York (J)	11:05		(Overnight stay)
	Dep. New York (J)	13:35	EA 1[illegible]	
	Arr. Aurland	16:08		
3. April 2, Thursday	Stay at Aurland			Spent the whole day at JFK Space Center (Overnight stay)
4. April 3, Friday	Dep. Aurland	08:15	DL 897	To Knoxville via Atlanta by Delta Airlines
	Arr. Atlanta	09:30		
	Dep. Atlanta	10:50	DL 532	Afternoon: Visit to Oak Ridge National Laboratory
	Arr. Knoxville	11:28		(Overnight stay at Knoxville)
5. April 4, Saturday	Dep. Knoxville	09:50	AA 300	To Washington by American Airlines
	Arr. Washington	11:00		(Overnight stay at Washington)
6. April 5, Sunday	Dep. Washington	09:30	EA 248	To New York by Eastern Airlines
	Arr. New York (L)	10:23		(Overnight stay at New York)

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Date and Day	Place	Time	Transport	Remarks
7. April 6, Monday	Stay at New York			Study and discussion (Overnight stay at New York)
8. April 7, Tuesday	Dep. New York (L)	15:00	AA 031	To Louisville by American Airlines (Overnight stay at Louisville)
	Arr. Louisville	17:59		
9. April 8, Wednesday	Stay at Louisville			Spent the whole day at American Air Filter Co. (Overnight stay at Louisville)
10. April 9, Thursday	Dep. Louisville	08:25	DL 356	To Minneapolis via Chicago by Delta and Northwest Airlines (Overnight stay at Minneapolis)
	Arr. Chicago (OR)	08:25		
	Dep. Chicago	10:05	NW 047	
	Arr. Minneapolis	11:16		
11. April 10, Friday	Stay at Minneapolis			Spent the whole day at Univac Co. (Overnight stay at Minneapolis)
12. April 11, Saturday	Dep. Minneapolis	09:10	UA 999	To Chicago by United Airlines (Overnight stay at Chicago)
	Arr. Chicago	10:18		
13. April 12, Sunday	Dep. Chicago	09:25	TW 425	To Albuquerque by Transworld Airlines (Overnight stay at Albuquerque)
	Arr. Albuquerque	11:13		
14. April 13, Monday	Stay at Albuquerque			Spent the whole day at SANDIA Laboratories (Overnight stay at Albuquerque)

15.	April 14, Tuesday	Dep. Albuquerque	09:40	CO 122	To Seattle via Denver by Continental Airlines
		Arr. Denver	10:40		
		Dep. Denver	12:00	CO 443	(Overnight stay at Seattle)
		Arr. Seattle	14:15		
16.	April 15, Wednesday	Stay at Seattle			Spent the whole day at Boeing Co. (Overnight stay at Seattle)
17.	April 16, Thursday	Dep. Seattle	10:50	UA 297	To San Francisco by United Airlines
		Arr. San Francisco	12:46		(Overnight stay at San Francisco)
18.	April 17, Friday	Dep. San Francisco	09.45	WA 601	To Los Angeles by Western Airlines
		Arr. LosAngeles	10:45		Noon: Visit to SPACE Co. (Overnight stay at Los Angeles)
19.	April 18, Saturday	Stay at Los Angeles			Study and discussion (Overnight stay at Los Angeles)
20.	April 19, Sunday	Stay at Los Angeles			Study and discussion (Overnight stay at Los Angeles)
21.	April 20 Monday	Dep. Los Angeles	16:15	UA 201	Forenoon: Visit to AACC
		Arr. Honolulu	19:45		Afternoon: To Honolulu by United Airlines (Overnight stay at Honolulu
22.	April 21, Tuesday	Dep. Honolulu	15:15	NW 009	To Tokyo by Northwest Airlines ..... crossing the International Date Line
23.	April 22, Wednesday	Arrival at Tokyo	19.05		Dispersed after arrival at Haneda Airport.

4. A BRIEF SKETCH OF THE CENTERS VISITED

4-1 JOHN F. KENNEDY SPACE CENTER (NATIONAL AERONAUTICS AND SPACE ADMINISTRATION)

(1) Location: Post Office Box 21222, Kennedy Space Center, Florida 32899, U.S.A.

(2) Date and time of visit: April 2, 1970, 9.00 A.M. to 4.00 P.M

(3) Brief Sketch of the John F. Kennedy Space Center

Kennedy Space Center is one of the constituent bodies of the National Aeronautics and Space Administration (NASA) of the United States of America, and forms one of the integral units in the chain of centers the NASA has set up for the space research like the Manned Space Center (Houston, Texas), Elms Research Center and Langley Research Center (Humbleton, Virginia), Marshall Space Flight Center (Huntsville, Alabama), Godard Space Flight Center (Greenbelt, Maryland), and Wallops Base (Wallops Island, Virginia) etc.

As the specialized agency of the NASA devoted to the launching of manned and unmanned space ships, it deals with the diverse problems related to the theory, method and technology of launching of rockets, besides developing new equipment for space flight. Again, this is also the center from where the NASA has been launching the manned Apollo space ships, unmanned lunar satellites, interplanetary space ships and scientific, weather and communication satellites etc.

The principal activities of the Center cover the diverse aspects of planning and guiding the space flights, not to tell of technical and administrative control. The other activities include designing, test assembly, inspection and drawing up contracts for the supplies. etc.

JOHN F. KENNEDY SPACE CENTER

This Center sprawls over an area of 88,000 acres (356Km^2) in Meritt Island off the east coast of Central Florida, and is divided into Industrial Area and Launch Complex Area. The Industrial Area accommodates the Head Office and various other facilities for training, testing, inspection, assembly and adjustment etc. The Launch Complex Area accommodates the giant Apollo assembly plant (VAB), control towers and a large number of launch complexes.

About 16,250 persons work in the Center: in all, 2960 persons from the government side and 13,250 from the various non-government agencies. The annual budget for the year 1970 was $ 393,900,000.

The Eastern Test Range, a constituent body of the Air Force Systems Command, is located just adjacent to the Center. The operation and maintenance of the largest rocket supply base in the free world are carried out from this test range. It also assists the fabrication of the launching facilities as well as launching proper, and monitors useful data of the rockets in flight with the range extending upto the Indian Ocean about 10,000 miles away. It also helps NASA in launching space exploration rockets for peaceful purposes. The facilities of this test range are also utilized by the Army and the Navy for developing the rocket weapons.

Formerly known as Cape Canaveral, this Center has been used ever since the end of the Second World War for developing diverse types of missiles, including the long range guided missiles; but with the formation of the NASA in 1958 and subsequent progress in the space exploration program, this Center has gradually turned into the rocket launching center of the NASA, and simultaneously the name has also been changed to John F. Kennedy Space Center.

(4) Outline of the Visit

4-A Sketch of the Visit

08.30: Reached the Vistor's Information Center,

08.45: Met Mr. Ostoski and Mr. Veekman, and boarded

the bus at 09.00 for visiting the center starting from the Industrial Area under the guidance of the above two officials.

While passing by the bus we got a glimpse of the Head Office, various types of inspection and training establishments and godowns from the outside. We saw the interior of the Parts Cleaning and Inspection Factory, Flight Handling Factory, Spacecraft Checkout Factory, A.O. Building and M7-355 Factory etc. Our main interest was to see the facilities connected with Clean Room.

At noon, we had our lunch at a cafeteria of the Center.

We boarded the bus again at 13.00 hour for visiting the Launch Complex Area. On the way, we dropped in at the Space Museum and saw the models of various missile rockets. However, some real rockets were also exhibited there. Next, we saw various facilities in the complex, fuel dumps, tracking station, Apollo space ship launching pad and the underground control room etc. Again, we also saw the huge building accommodating the assembly, adjustment and inspection facilities of the Saturn V rockets. We were especially impressed by the size of the vehicle used for towing the Apollo-Saturn V rockets as well as the mobile launchers.

We returned to the Visitor's Information Center at about 16.00 hour, and with this our visit to the Kennedy Space Center came to an end.

4-B. On Clean Room

An outline of the Clean Room facilities observed in various factories will be described below.

4-B-a: Parts Cleaning and Inspection Factory (vide Fig. 1)

This factory is devoted to dismantling, cleaning, inspection, re-assembling and adjustment of the various parts (max. 180 kg) obtained from the makers. In the dirt inspection room located just before the clean room, the parts are inspected with the help of a lens, and those found bad are dismantled and cleaned. The cleaning facilities comprise (i) trichloro-

ethylene washing tank, (ii) sulfuric acid hydrofluoric acid washing tank, (iii) water washing tank, (iv) nitric acid washing tank, (v) hydrochloric acid washing tank, (vi) water spray gun washing tank and (vii) caustic soda washing tank.

The approximate size of these tanks is about 1300 W x 1300 L x 1300 H, and the uncovered top is provided with push-pull type air curtain for protecting the workers. However, this protecting device is very imperfect, and hence the workers are instructed to use eye protectors. In fact, this room is very sultry, and the environmental conditions can be treated as very bad. Besides the above, there are also ultrasonic cleaners and pipe inspecting device to check-up the cleaning.

The clean room here is a conventional clean room of the class 10,000. The clean room is designed in such a way that one must pass through a front chamber containing shoe cleaner, air shower etc. The clean room contains 6 clean benches which satisfy the specifications of class 100. The operation is carried out on the basis of US Federal Specification No. 209.

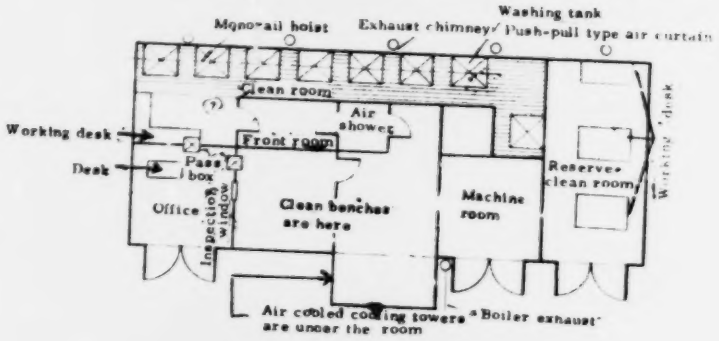

Fig. 1. Parts cleaning factory.

4-B-b: Flight Handling Factory (vide Fig. 2)

(i) Front Chamber

This room contains the wash basins, hand driers, shoe cleaners, toilette etc. The floor is laid with mosaic tiles so that it can be washed with water. The air shower consists of a perforated mechanism and the speed of the shower is [illegible].

(ii) Clean Room

HEPA filter is used here. The filter frame consists of wood, which is in turn fitted in another iron frame. The inner side of the HEPA filter is provided with a pre-filter for protection. It is a horizontal laminar flow type clean room, and it is also the principal working room.

(iii) Reserve Clean Room

It is a horizontal laminar flow type clean room where the space vehicle transported from the attached front chamber is inspected and washed.

(iv) Laboratory (vide Fig. 4)

This is alsoa conventional type clean room. It contains a mobile horizontal laminar flow tunnel. The size of the tunnel is about 16' x 16' x 16' H (4800 W x 4800 L x 3000 H). The side walls and the ceiling of the room are fitted with prexy glass panel mounted on aluminum frame. A part of the ceiling isof sliding type so that the crane provided on the ceiling of the room can be used. It can be converted into a class 100 clean room.

(v) Others

The dress is changed once in two days, but when contamination is high, the dress is changed daily. The hood allows only the face to remain exposed. The working hours on the week-days are 8.00~15.00 hour throughout the year.

4-B-c. Spacecraft Checkout Facility (vide Fig. 3)

The clean room here is of horizontal laminar flow type, and the size is 63' x 46' x 42'4"H (29,000 L x 14,000 W x 13,000 H). Inspection, assembly and adjustment of the space vehicles (for example lunar orbitor) are carried out here. The front room used for bringing in the space vehicle is provided with air lock, and is of the size 48' x 18' x 42'4" H (14,500 L x 5,500 W x 13,000 H).

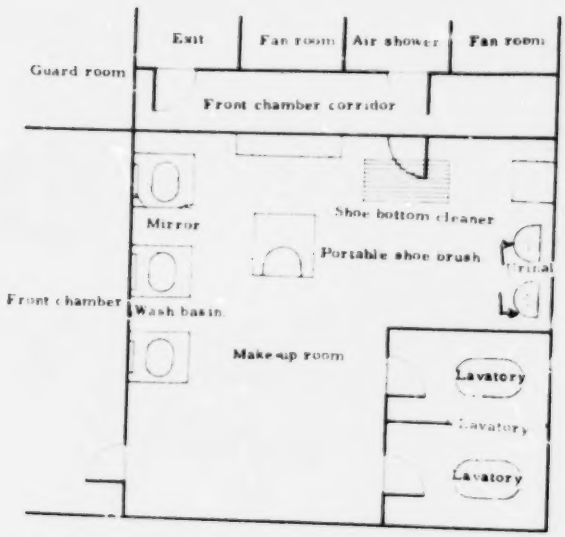

Fig. 2. Front chamber of the flight handling factory.

There are two cranes, one of 3T capacity and the other of 2T capacity, in the clean room, besides a 6T crane in the front room. The clean room has also pipe layout systems for providing 100 Psi (7kg/cm^2) compressed air, 150 Psi (10.5 kg/cm^2) nitrogen and creating vacuum. Three types of power viz. 110V, 220V and 440V can be used and air-cooled 185 UST cooling machine is used for cooling the air. In addition, there is also one 5 UST package, used primarily for blowing cool air at the time of inspection of the space vehicle. The entrance for bringing in the space vehicle is 16' x 36'6" H (5,000 W x 11,000 H) in size, and the door is sealed by expanding the tube-type rubber seal with compressed air.

The degree of cleanliness of the clean room is class 1,000, but just after the filter bank it is class 100. The temperature is 72°F $\pm$ 2°F (22.2 $\pm$ 1.1°C), the relative humidity is 45% $\pm$ 5%, the pressure inside the room is + 0.2 inch Aq (+ 5 mm Aq), and the illumination is 100 F.C. (1100 lux). There are also filter, walls made by M.S.A. Co. that can be used for 4 years, vinyl coating, and vinyl flooring on the concrete floor provided with paper seal.

JOHN F. KENNEDY SPACE CENTER

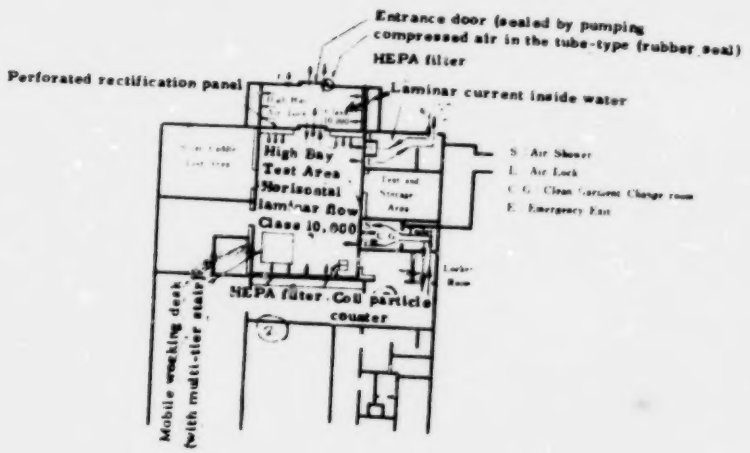
Entrance door (sealed by pumping compressed air in the tube-type (rubber seal)
HEPA filter
Perforated rectification panel
Laminar current inside water
High Bay Test Area Horizontal laminar flow Class 10,000
S. Air Shower
L. Air Lock
C. C. Clean Garment Change room
E. Emergency Exit
HEPA filter
Coil particle counter
Mobile working deck (with multi-tier stair)

Fig. 3. Spacecraft clean room in the A E building.

4-B-e. Clean Room of the A O Building (vide Fig. 5)

It caters to the unmanned spacecraft, and is the largest of its kind. It is, however, not in operation at present. The size is 176' x 47' x 50' H (53,000 L x 14,000 W x 15,000 H), and the front room for bringing in the vehicle is of the size 32' x 26'2" x 50' H (9,600 L x 7,900 W x 15,000 H). It can be sealed with compressed air.

There are two sets of cranes with 10T capacity (hook height 45'13, 500 H) in the clean room. Two similar cranes are also located in the front room. Normally 120 Psi (8.5 kg cm^2) compressed air is used, but the capacity can be stepped up to 225 Psi (16 kg/cm^2). The cleaning is carried out with the help of central vacuum device and portable vacuum cleaner both used simultaneously. The cooler has a capacity of 274 UST, and is of air-cooled type. Conventional filtering is carried out centrally and the clean air blows in through the side walls. The cleanliness class is 100,000. The walls consist of gypsum boards finished with epoxy paint. The ceiling consists of flash panel, and mercury lamps are used for illumination.

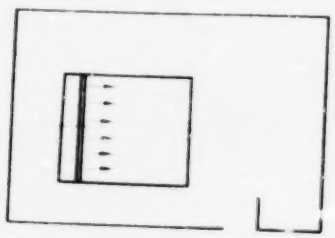

Fig. 4. Laminar flow tunnel inside the laboratory

4-B-f. M 7-355 Factory (vide Fig. 6)

Here the employees of the North American Rockwell Co. and Mcdonell Douglass Co. were engaged in assembling and adjusting parts which appeared to be destined for the Apollo spacecraft. The security steps were very strict, and carrying in the cameras was forbidden. We were made to put on garment and hood in the front room which was equipped with shoe cleaners. After this, we entered the clean room.

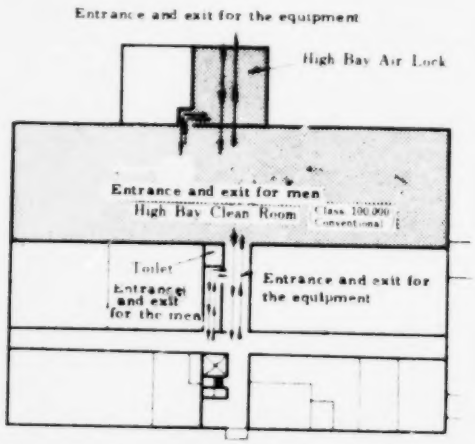
Entrance and exit for the equipment
High Bay Air Lock
Entrance and exit for men
High Bay Clean Room
Toilet
Entrance and exit for the men
Entrance and exit for the equipment

Fig. 5. Clean room in the AO building

It is a conventional type clean room of size 60' W x 170' L x 50' H. It is almost dark as the illumination is very poor. The air entered from two tier diffuser located on the side wall and returned through another two tier exit located also on the side wall, but near the floor. The walls are painted in blocks,

and the concrete of the floor is also painted, although the paint had peeled off here and there, and there were also many cracks.

Various types of testing facilities are located here. For example, 2 vacuum chambers of diameter about 7m are installed here to carry out tests under the conditions existing in the space at an altitude of about 60,000 ~ 70,000 m. Again, a number of large sized working platforms are also kept here.

There are exposed pipings for compressed air, nitrogen gas and vacuum. The air conditioning ducts are also similarly exposed inside the room. The ceiling is equipped with two relatively large sized cranes. There is an air sealed door at one end of the building (room), through which the components are brought in and taken out.

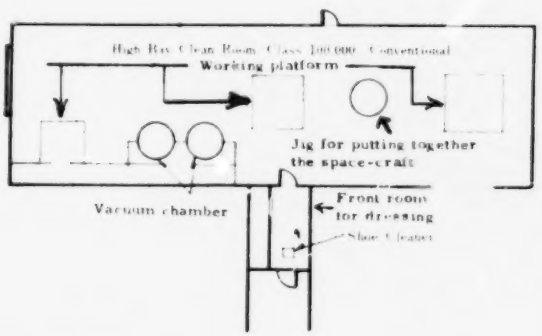

Fig. 6. Clean room in the M 7-355 factory.

4-B-g. Space Vehicle Assembly Building (VAB)

The Saturn V rockets for the Apollo Space Program are inspected, assembled and adjusted here with great efficiency. It occupies an area of 32,350 m^2; and the height of the high bay area is 160 m and that of the low bay area is 64 m. As the atmosphere inside is under strict security control, details of the work taking place here were not very clear. Just it was known that the air coming in passes through the filter beforehand. It appeared that only those places were air conditioned where it was felt necessary.

JOHN F. KENNEDY SPACE CENTER

4-C. Other Items Related to C. C. and Impression

Every Quality Control Section in each NASA Center (for example, Manned Spacecraft Center, Marshal Space Flight Center, Kennedy Space Center, etc.) has a C. C. Cell staffed with a few experts and headed by a manager to look after the C. C. Control Program associated with space development equipment, all the parts suppliers (private companies) and all the supporting organizations have C. C. Cell set up in their quality control sections to look primarily after contamination control.

These government and private bodies maintain close cooperation amongst themselves and are busily engaged in solving various problems related to C. C. raised by the space development program. Fruition of these efforts can be seen in the compilation of various specifications, guide books and standards etc., and the enormous expenditure incurred over the past two decades can be considered to be very well planned investment ultimately contributing its share in the successful implementation of the space development program.

Because of very little time at disposal, the team could not have a detailed overall idea of the works carried out in the Kennedy Space Center related to the problems raised by C. C. Again, the clean rooms also could not be studied in detail as work was not in progress in many places. However, a fairly good idea was obtained after going through the following documents.

i) Guideline and Procedures for Operation of NASA Unmanned Spacecraft Assembly and Checkout - Clean Room Facilities

ii) NASA Contamination Control Documents

a) SP 5045 "Principles of Contamination Control"
b) CR 6124 " Contamination Control Handbook"

The impression we got after seeing the gigantic clean rooms at the Kennedy Space Center is that enormous expenditure is incurred for just operating and maintaining these. Such establishments can be maintained only by the state-controlled

to the goal of successfully implementation of grandoise program, and is indeed beyond the dream of the private companies where profit motive forms the foundation.

In clean rooms, the degree of cleanliness to be achieved immediately downstream of the filter bank can be planned from the performance and system of the filter, but for economic operation it is necessary to pay great attention to the methods of working and prevention of production and accumulation of the contaminants constantly, and also devise steps based on actual findings and experience. Considered from this angle, there is enough scope for improving the relationship between the clean room and the system of work.

In short, the programme of contamination control will be successful only after establishment of clean rooms, selection and training of personnel, monitoring based on proper standard specifications, and a management system capable of managing the show efficiently.

(5) Persons interviewed

Mr. J. P. Ostoski (North American Rockwel CoCoa Beach)

Mr. Veehman

(Reporter: H. Chiba)

4-2 OAK RIDGE NATIONAL LABORATORY

(1) Location: Oak Ridge, Tennessee, 37830 U.S.A.

(2) Date and time of visit: April 1970. 1.00 P.M.

(3) Brief Sketch of the Oak Ridge National Laboratory

It is one of the largest atomic power research centers in the world sprawling over an area of about 92 square miles on the eastern part of Tennessee. It is about 20 miles from Knoxville and about 10 miles from Oak Ridge. (Photograph 1).

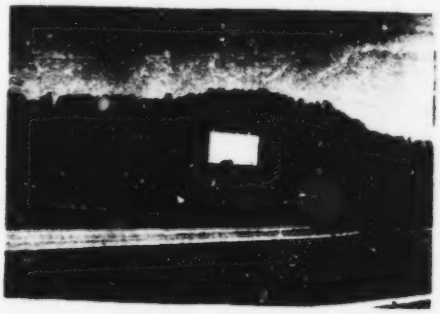

Photo 1.

It was known as Manhattan Engineering District in the Atomic bomb program of September 1942, and at present it contains a number of laboratories like K-25 (gas diffusion uranium enriching plant), Y-12 and X-10 etc., besides a large number of atomic reactors.

X-10 is primarily engaged in atomic energy research and Y-12 is carrying out researches in the field of isotopes. Both are operated by Union Carbide Co. with the assistance of the Defence Department, NASA, State Department, Health

Department. Education Department and Health Department, amongst others. About 100 research groups are engaged in studying peaceful use of atomic energy in the following 8 fields.

1) Development work in reactor technology.

2) Development work in chemical technology

3) Basic research in the fields of biology, chemistry, physics, metallurgy and health-physics.

4) Specialized training and education , such as reactor operation.

5) Radiation protection work.

6) Research and development in the production and use of stable and radioactive isotopes.

7) Research into the controlled fusion process.

8) Studies for the Department of Interior's Office of Saline Water.

(4) Outline of the Visit

During this visit, the team was not permitted to see the interior of the laboratories. Cameras were also not allowed. The working of the laboratories was explained through lectures illustrated with slides. The lectures were delivered by Mr. J.C. Little, Mr. R.H. Liddle and Mr. C.A. Burchested, and were on the following themes.

1) Mr. J.C. Little spoke on "the clean rooms of Y-12 and NASA".

2) Mr. R.H. Liddle spoke on "Contamination control of the Apollo lunar samples return container and supporting hardware".

3) Mr. C.A. Burchested spoke on "Air filters used in the atomic power research centers and the NASA".

As the lecture of Mr. Little covered more or less the topics already published in the May 1966 issue of "Kuki Seijo" (Japan Air Cleaning Association Journal) and the October 1968 and May, July and August 1969 issues of "Heating, Piping and Air Conditioning", it will be omitted here. The lectures delivered by Mr. Liddle and Mr. Burchested will be discussed here incorporating the latest information obtained after the Mission's return to Japan.

(4)-1. Contamination control of the Apollo lunar samples return container and supporting hardware – by R.H. Liddle

(4)-1-1. Introduction

The author got the chance to hear Mr. Liddle again on the same theme at the conference of the AACC held at Ross. The author tape recorded the speech and photographed various collecting devices and containers exhibited in the conference. Reference will be made to these while describing the original speech.

The Apollo Lunar Sample Return Container is generally abbreviated as ALSRC, and is intended for bringing back to earth the lunar materials collected by the astronauts as a part of the 'Lunar Sample Collection Project' of the Appollo program. In case these containers get contaminated with terrestrial materials and bacteria by chance, then not only precise analysis of the lunar materials will be impossible, but also there is the danger of the moon getting contaminated with earthly things and the bacteria spreading in the space. One can easily realize the importance of properly sterilizing and cleaning these containers even from the point of survival of life on this earth when he takes into consideration the fact that the terrestrial bacteria have amply demonstrated their prowess by surviving for more than two and half years in the hostile lunar environment where the vacuum is of extremely high degree, not to tell of the extreme fluctuation in temperature. Thus, in view of the mission it should accomplish, the ALSRC should be

highly precise and reliable and capable of maintaining high degree of vacuum. Besides, the construction should also guarantee easy maneuverability even in the most unfamiliar environmental conditions. As the lunar materials are to be analyzed to the extent of p.p.b. (parts per billion), it can be well imagined how much the precision of the results will be affected even if traces of the earthly substances contaminate the container. This being the situation, great emphasis has been laid on the following points in enforcing contamination control during cleaning of the ALSRC.

I. Washing is to be continued till the degree of superficial contamination decreases to less than 10^{-8} gm/cm^2 (weight of contaminant adhering to 1 cm^2 of the surface).

II. A testing method is to be developed that will guarantee that the degree of superficial contamination is of actually of the order of 10^{-8}/cm^2 or less.

III. Proper modification is to be effected in the Class 100 vertical laminar flow (VLF) type clean room so that it can be used as the washing room.

IV. Active carbon is to be used to remove the vapor of the washing liquid from the air of the clean room.

V. Fire proof test is to be carried out with the active carbon saturated with the washing liquid.

VI. A study is to be carried out on the concentration distribution of the liquid inside the Class 100 VLF type clean room.

VII. Tests are to be conducted on the actions of the washing liquid and of ultrasonic disinfection.

Next a brief description of the Y-12 plant, which has been assigned the task of cleaning the equipment related to ALSRC, will be given. The Y-12 plant of Oak Ridge is associated with the Apollo project of the NASA for the last four years. It has also undertaken in the designing and assembly of vacuum chamber system and environment control system of lunar material

receiving facilities at Houston, as well as the devices for collecting, accommodating and transporting the lunar material. The ALSRC and the related devices have been designed and assembled on the basis of the following two design specifications.

I. The weight of the devices should be minimum but at the same time strong enough to allow the bringing back of the lunar material without any trouble.

II. They should be able to withstand the degree of vacuum which exists on the lunar environment.

The technologists working at the Y-12 plant have developed high degree vacuum device for remote control manipulation of the lunar samples brought back by the astronauts. This device consists of a vacuum chamber, vacuum glovebox and a mechanism for inspecting and handling the lunar samples in the state of high degree of vacuum without the fear of getting the things contaminated biologically, all the three being operated by remote control system (Fig. 1).

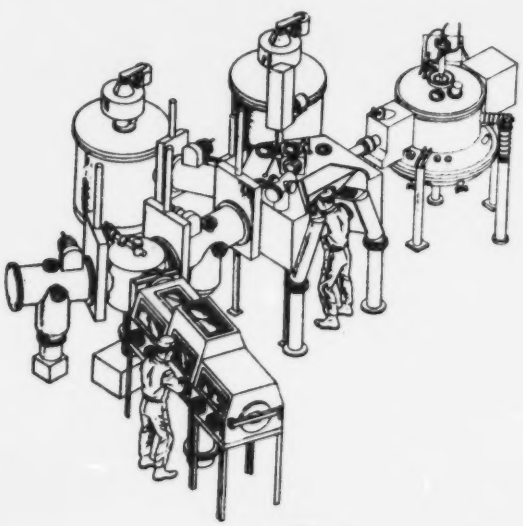

Fig. 1.

After return to earth from the moon, the exterior of the ALSRC is disinfected and cleaned inside a glovebox maintained

at ordinary atmospheric pressure. Next, it is transferred to a vacuum glovebox maintained in a state of vacuum of about 10^{-6} torr (about 10^{-9} atmospheric pressure). The greatest difficulty that was faced at the time of developing this vacuum glovebox was the assembly of the ultra-high vacuum chamber which could be operated by a manipulator (magic hand) in the vacuum state of 5×10^{-11} torr (the pressure existing on the lunar surface). This highly sophisticated chamber was needed for accommodating the lunar samples brought back by the containers sealed in the highly vacuous state of the lunar surface in an environment similar to that existing on the moon.

The Y-12 plant is also designing, fabricating, testing and monitering sophisticated environment control system for the Low-Level Radiation Counting Laboratory, located underground. This laboratory is engaged in monitoring the radiation of the lunar samples, and has a counting room of an area of 1340 sq.ft. as well as a control room. It is a unique laboratory in the sense that the effects of external radiation (like cosmic rays etc.) have been reduced to practically zero here. Thus, an accurate measurement of the radioactivity of the lunar samples is possible here. This laboratory is located about 40 ft underground and is enveloped in water, air and other materials with very little natural radioactivity. A sketch of the laboratory has been shown in Fig. 2.

Next, the various devices used for collection will be described in detail.

In general, these devices should satisfy the following conditions. The materials used in the construction should be chemically stable and at the same time should be capable of withstanding the rigours of thorough cleaning. After a thorough study, aluminum, stainless steel, teflon, silicon fluoride, and indium-silver alloy were found to satisfy the above requirements. Again, while using these materials, a thorough check-up is carried out to ensure whether the contents of lead uranium etc., which are harmful to the human beings, are below the permissible limit or not.

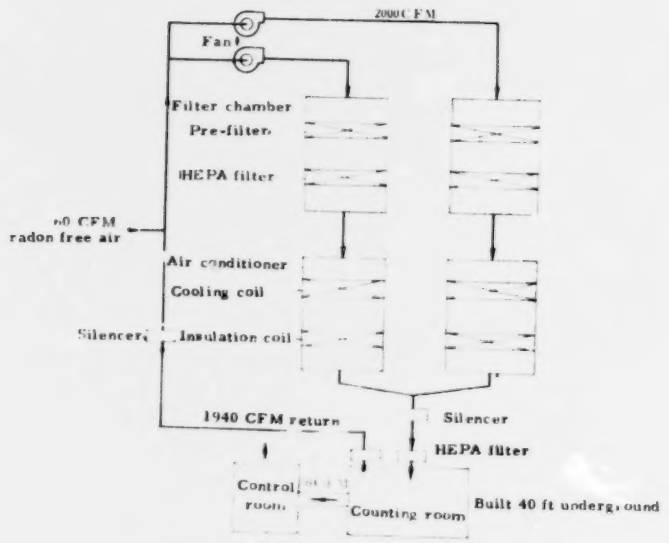

Fig. 2. Sketch of the Low Level Counting Laboratory.

(4)-1-2. ALSRC and the Implements Used in Collecting the Lunar Samples (Photograph 2)

The implements for collecting the lunar samples as well as the containers to hold the samples have been designed especially for collecting the lunar samples without the danger of local contamination and bringing them back to the earth. Hence, these devices do not affect the analysis of the samples in any way. Again, they are very stable chemically and light in weight. They are made from aluminum, stainless steel and teflon etc. as these materials satisfy the above requirements very well.

After construction of the above implements and containers, they are cleaned ultrasonically inside with extremely clean liquid in a clean room of Class 100 so that the degree of surface purity becomes less than 10^{-8}gm/cm^2. This degree of cleanliness is confirmed by Lins's method of measuring contaminants inside solution using gas chromatography.

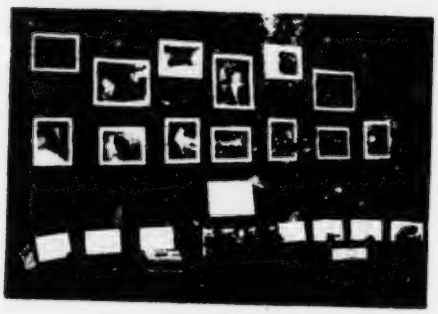

Photo 2. The ALSRC exhibited.

(4)-1-2-a. ALSRC (Photograph 3)

The ALSRC has been designed to carry the hardware for collecting the lunar samples to moon in vacuuous state and then bring back the lunar samples to earth also in vacuuous state.

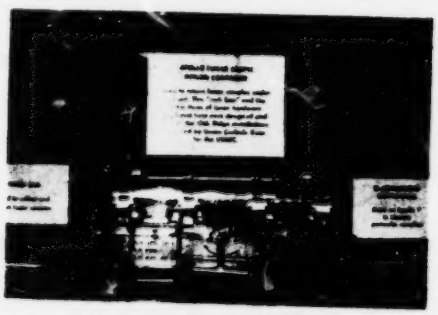

Photo 3. ALSRC

This container is of the size 19" x 11 1/2" x 8", and aluminum 7075 has been used as the principal construction material. This aluminum alloy has been selected because it possesses extremely high strength with respect to weight. Its construction consists of the body, lid and external accessories The lid and the body have been forged from the same aluminum sheet and they have been finished by heat treatment and machining alone. The only welding has taken place at the spot where the thermocouple vacuum gauge has been fixed. The lid is firmly attached to the body with four stainless steel bands. As gasket , silicon fluoride ring seals have been fitted on the

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lid and the body for maintaining the vacuum inside. Again, the protrusions provided on the lid have been well designed to fit in tightly in the grooves of the body filled with indium-silver alloy. The degree of vacuum inside the container is shown by the vacuum gauge. Originally, element of 1 mil (1/1000 in) diameter was used in the vacuum gauge, but as this proved to be too weak, 3 mil element has been used.

The ALSRC surface has been polished highly to reflect the radiant heat in order to control the temperature inside the container.

The interior of the ALSRC has been reinforced with ribs, and the section free from the ribs has a thickness of 45 mil in terms of cell dimension. The weight when empty is 11.5 lb. The interior has also been provided with a mesh made from 10 mil aluminum wire in order to prevent damage to the container by the collecting implements or the lunar samples. The cleaning of the aluminum mesh proved to be one of the most tricky problems. This is because the aluminum used in a single container has a surface area of about 2,000 in^2. Besides the above mesh, mesh pads have also been used for packing the contents of the container. The size of these pads is 6" x 10 1/4".

(4-1-2-b. Other Implements (Photographs 3, 4)

(i) Special Environmental Sample Container (SESC).

It is the container for bringing back to earth the lunar samples during the return flight in a state of vacuum as that existing on the lunar surface or as close to it.

(ii) Gas Analysis Sample Container (GASC)

This container is used for bringing back the samples to be used for analyzing the gas emitted by them at various temperatures under the state of high degree of vacuum.

(iii) Magnetic Shield Sample Container (MSSC)

This container is used for bringing back the lunar samples for studying their magnetic characteristics.

(iv) Contingency Lunar Sample Container (CLSC)

Normally, there is some time gap between the landing of the astronauts on the lunar surface and collection of the samples. This container is to be used during some emergency when the astronaut cannot carry on the collection program as per the schedule.

(v) Weigh Bag

It is a weighing bag for facilitating the weighing of the samples immediately as they are collected before accommodating them into the container.

(vi) Solar Wind Composition Experiment Bag (SWCEB)

Instruments for studying the solar wind on the lunar surface are accommodated in this bag, and are brought back to earth after carefully placing them inside the ALSRC.

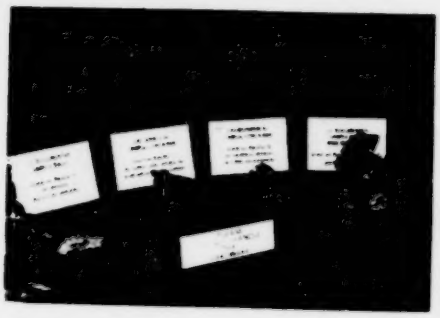


Photo 4.

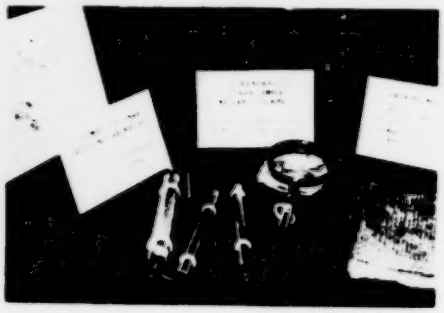


Photo 5.

(4)-1-4. Cleaning Operation

(4)-1-4-a. Pre-Cleaning

As has already been stated, the ultimate degree of cleanliness of the ALSRC should be less than 10^{-8} gm/cm^2. In achieving this final degree of cleanliness, it is necessary to carry out pre-cleaning operation (Level I ~ III) as shown in Fig. 3. It is necessary to lighten the load of the final cleaning

(Level IV) by removing the dirt produced during grinding etc. at the pre-cleaning stage. It is also necessary to reduce the weight of the surface contaminants to below 10^{-5} gm/cm^2 by pre-cleaning in order to achieve the final degree of cleanliness. It is also extremely important to ensure that the objects thus pre-cleaned do not suffer from any corrosion due to the process adopted.

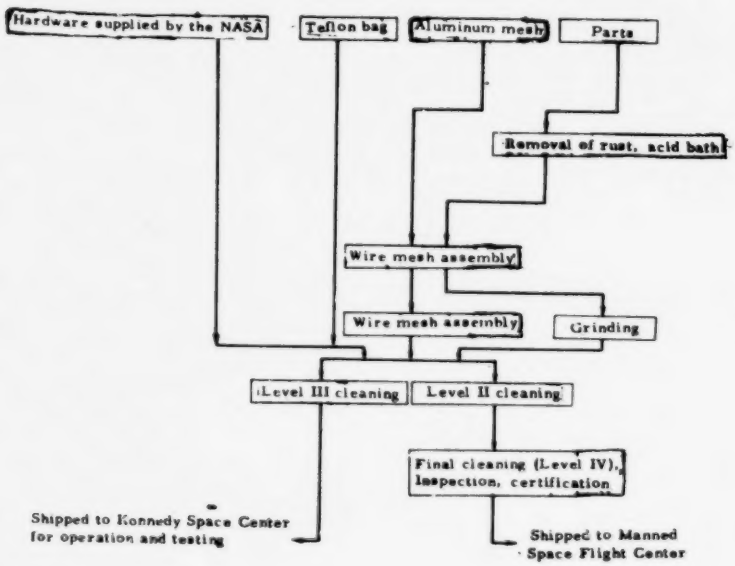


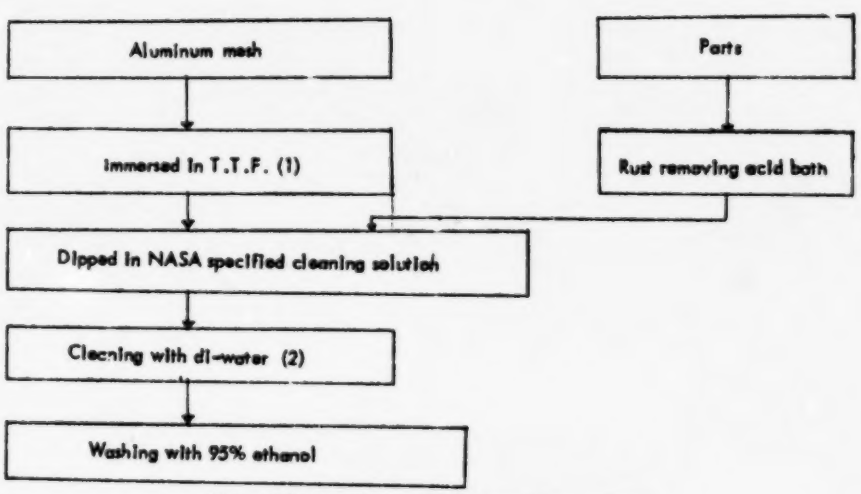
Fig. 3. Flow chart of the cleaning operation.

(4)-1-4-b. Final Cleaning.

Because of the extremely sophisticated nature of the mission to be accomplished by the ALSRC, it demands extremely high degree of cleanliness unknown in the annals of science so far. Not only that it should be free from the inorganic contaminants, but also it should be free from the organic contaminants as well. The ALSRC accumulates diverse types of contaminants during assembly and adjustment, and once these contaminants get mixed up with the lunar materials, then it can be well imagined that reliability of the results of analysis will come down to a great extent. Hence, it is

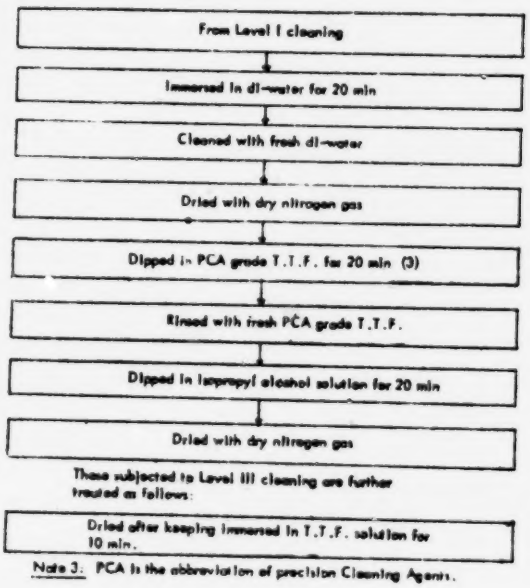
necessary to reduce the amount of the terrestrial contaminants to a level where it will not be possible to detect them by any method of analysis during the stage of final cleaning. After a careful study, the level of the amount of the contaminants after final cleaning was fixed at below 10^{-8}gm/cm^2. A very complicated method has to be employed to achieve this degree of cleanliness. Next the flow charts of the different levels of cleaning will be explained one by one. Although it has not been mentioned in Fig. 3, yet it must be stated here that ultrasonic method is employed in cleaning.

(4)-1-4-c. Level I Cleaning.



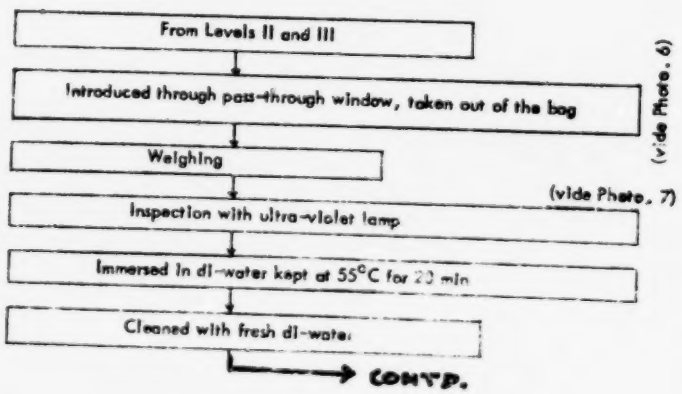
Notes: (1) abbreviation of trichlorotrifluoroethane
(2) abbreviation of deionized water.

(4)-1-4-d. Levels II – III Cleaning


From Level I cleaning
Immersed in di-water for 20 min
Cleaned with fresh di-water
Dried with dry nitrogen gas
Dipped in PCA grade T.T.F. for 20 min (3)
Rinsed with fresh PCA grade T.T.F.
Dipped in Isopropyl alcohol solution for 20 min
Dried with dry nitrogen gas
Those subjected to Level III cleaning are further treated as follows:
Dried after keeping immersed in T.T.F. solution for 10 min.

Note 3: PCA is the abbreviation of precision Cleaning Agents.

(4)-1-4-e. Level IV Cleaning


From Levels II and III
Introduced through pass-through window, taken out of the bag
(vide Photo. 6)
Weighing
(vide Photo. 7)
Inspection with ultra-violet lamp
Immersed in di-water kept at 55°C for 20 min
Cleaned with fresh di-water
CONTD.

Kept immersed in a mixture of 3:1 benzene – isopropyl alcohol solution and subjected to ultrasonic treatment for 20 min.

↓

Immersed in PCA grade T.T.F. solution for 20 min

↓

Kept immersed in a mixture of 3:1 benzene – isopropyl alcohol solution and subjected to ultrasonic treatment for 20 min.

↓

Kept immersed in a mixture of 2:1 benzene – isopropyl alcohol solution for judging contamination and subjected to ultrasonic treatment for 10 min.

↓

Transferred to a stainless steel table and dried in air.

The liquids used for cleaning at level IV are changed for every 10,000 cm^2/gal.

Note (4): The solution for checking contamination is used at the rate of 25,000 cm^2/gal.

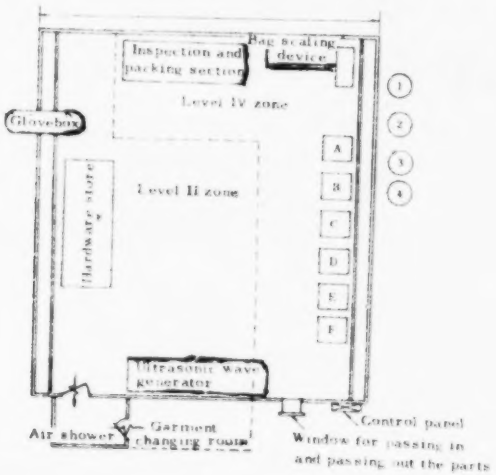
Photo 6. – Through window

Photo 7.

(4)-1-5. Cleaning Room

(4)-1-5-a. Cleaning Room for Levels II & III Operations

The layout has been shown in Fig. 5. It is made of wooden frame and plastic sheets, and the air that is circulated passes through the HEPA filter. The pressure inside the room is kept at a slightly higher level so that the excess air leaks outside. The temperature and humidity are controlled at ordinary level just for the sake of the persons working there. The Level II clean room accommodates three cleaning tanks provided with ultrasonic cleaning device made of steel and a test stand with ultra-violet lamp. The three tanks contain



Note: A: Detonized water

B: Trichlorotrifluoroethane (PCA)

C: Isopropyl alcohol (IPA) - benzene

D: " "

E: Place for storing the equipment after washing

F: Tank for contamination checking solution (Isopropyl alcohol - benzene)

1: PCA (fresh)

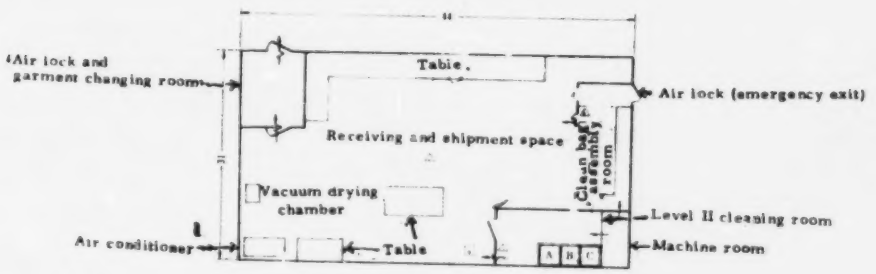
2: D-I water (fresh)

3: PCA (after use is over)

4: Isopropyl alcohol - benzene (after use is over)

Fig. 4. Aluminum mesh assembly room.

di-water, T.T.F., and isopropyl alcohol respectively. The air supplied to the clean bag assembly room also passes through the HEPA filter. The degree of cleanliness at the Level II clean room is measured with the help of automatic particle counter (Made by Royco Co.) and membrane sampling filters placed in the positions shown in Fig. 5.



Notes: (i) Cleaning tanks

A: Deionized water

B: Trichlorotrifluoroethane

C: Isopropyl alcohol

(ii) Air samplers:

△, △, △ : Membrane filter

: Automatic particle counter (Royco)

Fig. 5. Level II cleaning room.

An example of the results achieved here has been shown in Table 1. Considering that it is a relatively crude type of clean room, yet a study of the results will show that it has done a splendid job. Tribute for this should be paid to strict control and maintenance as well as to the conciousness of the people working there with respect to contamination. At present, the prospect of making this a permanent establishment is under active consideration. Under he new proposal, the new room will be enveloped in iron plates, the return air will return after passing through double wall, the supply air will be supplied through perforated ceiling, and the temperature will be controlled strictly.

(4)-1-5-b. Aluminum Mesh Assembly Room

Aluminum mesh assembly is carried out inside the clean room shown in Fig. 4. This clean room is of vertical

TABLE 1

Particles in level II & III cleaning room

Method of measurement	Particle size (μ)	No. of particles (particles/cu.ft.)
Automatic particles counter (1)	above 0.5	1300
	1.0	200
	2.0	85
	5.0	10
Microscopic observation (2)		
Clean room	5.25	3
	>25	1
Bag assembly room	5.25	<1
	>25	<1
Receiving and shipment space	5.25	1
	>25	<1

(1) Value for 10 hours of operation
(2) Sampling carried out according to ASTMF 25-68

laminar flow type with the HEPA filter fitted on the ceiling. The return air is taken from the lattice floor and the temperature is controlled here. This room was originally built for measurement of the instruments, and the temperature is maintained here within the range $\pm 1/4^{\circ}F$. The relative humidity is maintained at 45% $\pm$5%. Clean bench and garment changing room have been added later on when it was changed into assembly room. Excess pressure of about 13 mm Aq is maintained inside the clean room, and the amount of air exhausted through the change room is 2550 CMH (makeup air). The total amount of air supplied is 39,000 CMH, and the speed of supply is about 0.35 m/s. The aluminum mesh is assembled on clean bench with horizontal laminar flow, and the tools used in the assembly are cleaned

every day in the Level II cleaning room. Photograph 8 shows the assembly of mesh to be used in the ALSRC in progress.

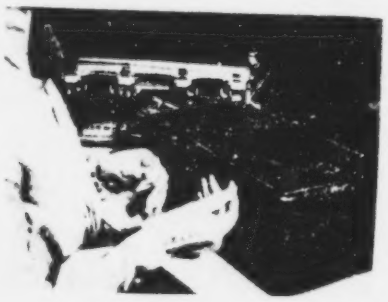


Photo 8.

Monitoring of this clean room is carried out with the help of automatic particle counter (Made by Royco Co.) and membrane sampling filter. An example of the results obtained has been shown in Table 2.

TABLE 2

Particles in the aluminum mesh assembly room

Method of measurement	Particle size (μ)	No. of particles (particles/cu. ft.)
Automatic particle counter (1)	Above 5	Average: 1 Maximum: 3 Minimum: 0
Microscopic observation (2)	5-25	Average: 2(3)
Microscopic observation (3)	>25	Average: 3(3)

(1) The result of working for 7 hours has been measured 9 times

(2) Sampling carried out according to ASTMF 25-68

(3) Mean value of the 32 measurements carried out with the results of 8 hours of operation.

(4)-1-5-c. Level IV Cleaning Room (Final Cleaning Room) (Photograph 9)

Level IV cleaning is carried out inside a VLF type clean room of class 100. The floor plan has been shown in Fig. 6

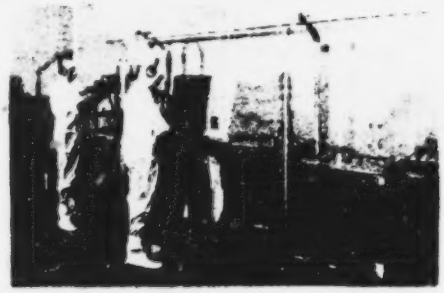


Photo 9.

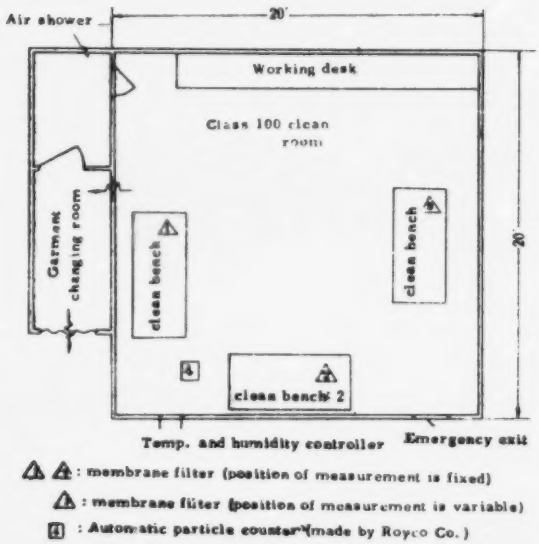


Fig. 6. Floor plan of the level IV cleaning room.

This clean room can be divided into two zones, viz., Level IV zone and Level II zone. In the Level IV zone there are 6 stainless steel cleaning tanks, one bag sealing device and a table for inspection and packing. In the Level II zone there are ultrasonic wave generator and hardware store. Furthermore, the

air shower door and the transfer glovebox are also adjacent to the Level II zone.

The tanks placed along the eastern wall of the room contain di-water T.T.F. and isopropyl alcohol-benzene solution. High purity benzene and isopropyl alcohol are kept in the level II zone in 1 gallon glass container, and all other solutions, both fresh and used, are kept in drums in the laboratory which is a class 10,000 room adjacent to the east wall of the room. The air supplied comes into the clean room from the ceiling after passing through two types of pre-filter, active carbon filter and a two-bank HEPA filter, and is expelled through the lattice floor. This expelled air returns to the air conditioner via a duct provided with double wall. The air flow speed inside the room is about 0.45m/s, and the volume of air supplied is 53,000 CHM, of which 2,550 CHM escapes to outside via the air lock. The room temperature is controlled by proportionate regulation of three way cold-water valve with the help of a thermostat located inside the room, and the fan dumper is controlled with the help of pressure regulator. The pressure inside the room is maintained at plus pressure. Not only the floating dust is thoroughly filtered, even the vapor of the solutions used is removed with the help of active carbon filter. The use of the two sets of HEPA filter was motivated by the following two reasons, (1) to set up as clean an environment as possible, and (2) to eliminate the necessity for replacing the HEPA filter provided on the ceiling with new ones and to make the filter system of the VLF device located on the ceiling a perfect one. Here, leak test can also be carried out repeatedly.

(4)-2. Air Filters used in the Atomic Power Research Centers and the NASA

This lecture illustrated with slides was also delivered by Mr. C.A. Burchsted. This lecture covered diverse aspects like construction of HEPA filter, its installation, post-installation problems, testing methods and the application of the filter to atomic power equipment etc. As the space here is very limited, a brief outline of the lecture will only be given here. The contents of the book 'Design, Construction and Testing of High-Efficiency Air Filtration System for Nuclear Application' by Burchsted have also been given at the end of the paper for

reference. The Japan Air Cleaning Association has a project to translate and publish this book.

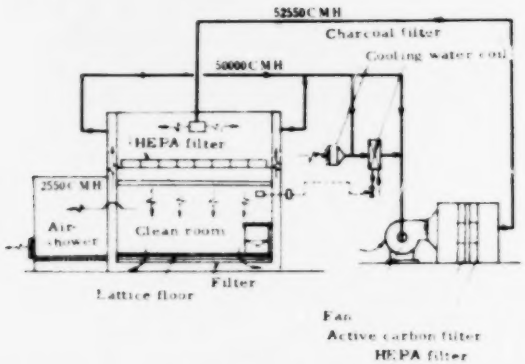


Fig. 7. Layout of the duct system of the Level IV cleaning room.

(4)-2.1. HEPA Filter

The HEPA filter (also known as Absolute, super-interception, very-high-efficiency, AEC CWS [Chemical Warfare Service] filter) can be considered to be the most satisfactory and at the same time most economical device for removing submicron grade particles from air or other gas current with extremely high efficiency.

The HEPA filter is defined as a zig-zag shaped discardable type filter made from dry filtering material, and satisfying the following three conditions.

(1) It possesses a removal efficiency of more than 99.97% for particles of the size 0.3 μ.

(2) At the rated volume of air, the initial maximum air resistance is 25.4mm (1") Aq.

(3) The entire medium is put inside a stout casing.

(4)-2-1-a. Performance

(i) Efficiency and Resistance: The efficiency and initial resistance of the HEPA filter are determined in the factory

before shipment according to the procedure developed for the purpose by the US Army[1] and the US Atomic Energy Commission[2]. However, almost all the fabricators of the equipment related to atomic energy request the two AEC Quality Assurance Stations located at Oak Ridge and Richland[3] to confirm the maker's certification. As this confirmation test concerns the filter which occupies an extremely important place in quality control, users are encouraged to have their filters pass through this test even if the use in not intended for any government project. In exchange for this service, the AEO charges only the actual cost as the fee[4]. Both the filter makers as well as the Q.A.S. carry out the test using D.O.P. (dioctyl phthalate) aerosol.

The HEPA specifications[5] prepared by the AACC (American Association for Contamination Control) divides the HEPA filters into three classes depending upon their performance.

Type A: Overall penetration (= 100 - filter efficiency) is measured at the rated volume of air.

Type B: Overall penetration[6] is determined at the rated volume of air and at 20% of the volume of air.

Type C: Scanned filter: The special type test carried out for filters used in equipment like clean bench is known as scanning.

Type A filters are used mainly in the spot where the air of the clean room etc. is circulated and filtered.

Type B filters which undergo the Z-flow test are recommended for use in the exhaust system of the contaminated air.

Almost all the filters which have undergone test at QAS have shown about 99.99% efficiency (only 1 particle passes out of 10,000). The volume of air filtered and the resistance value are determined simultaneously with the efficiency test, and these values are stamped on the filter casing.

(ii) Volume of Air: The standard sizes of the five types of HEPA filters used in the exhaust of the contaminated air have been shown in Table 3. 1000 CMF size is recommended in the bank system (multi-layer system). There are other filters also besides those mentioned above, but it is desirable not to use them as the experience till now has shown that these are difficult to obtain and are extremely costly.

TABLE 3

Standard H E P A Filter Sizes

Capacity at Clean-Filter Resistance of 1.0 in H_2O (scfm)	Filter Face Dimensions (in.)	Filter Depth less Gaskets (in.)
25	8 x 8	$3\frac{1}{16}$
50	8 x 8	$5\frac{7}{8}$
125	12 x 12	$5\frac{7}{8}$
500	24 x 24	$5\frac{7}{8}$
1000	24 x 24	$11\frac{1}{2}$

(4)-2-1-b. Construction of the HEPA Filters

Typical constructions of the open face-type HEPA filters with wooden casing and steel casing have been shown in Fig. 8. The core (filter pack) consists of paper made from fibre glass or cellulose asbestos (filtering material) folded in a zig-zag manner on corrugated separators. These separators improve the passage of air besides increasing the strength of the core.

The core is completely enveloped in frame made of wood or steel, and sealed with adhesive in order to deprive it of its elasticity.

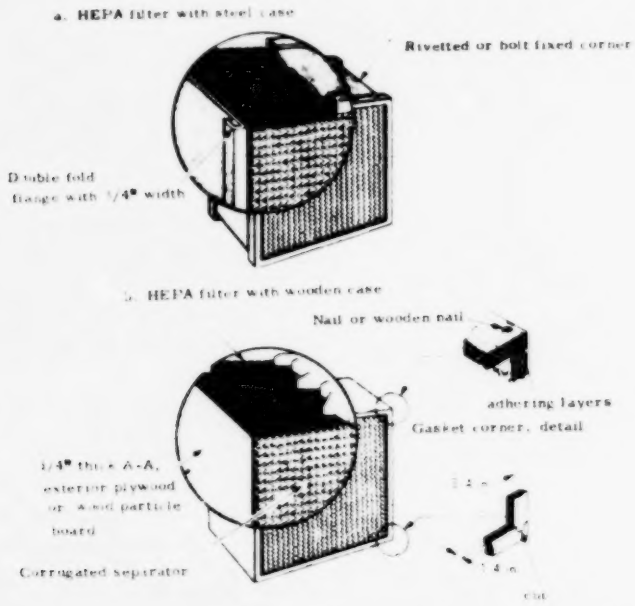


Fig. 8. Construction of the open face HEPA filter unit.

(i) Filter Paper: The filter paper is made of extremely fine submicron grade fibre. Organic binder (maximum 5% in terms of weight) for adhesion of the fibres is added at the time of making the paper. Glass fibre is used as the raw material at the time of making the fire-proof filter paper. Combustible filter papers are also sometimes used for specific purposes, and these are made from cellulose and asbestos fibre.

(ii) Separator: Aluminum foil and asbestos paper are ordinarily used as the material for the separator. Sometimes Kraft paper and various types of plastics are used in making the separator, but these cannot be recommended for equipment related to atomic energy as these are weak to heat.

(iii) Sealant: Ordinarily adhesives resistant to heat, moisture and hardening are used as the sealant for the adhesion of the

core and the filter case. However, some makers also use Urathane foam. For filters to be used continuously at high temperature (400°C), compressed fibre glass mat, high-temperature silicone and fusion resistant substance are used as the sealant. Such sealants should satisfy the following requirements.

(1) It should be moisture resistant.

(2) It should not undergo any deterioration or loss in elasticity when working repeatedly under the conditions of cold~hot, dry~moist.

(3) It should not develop cracks or get detatched from the frame at high temperature (750°C, 5 min).

(4) It should strictly maintain the adhesion between the filter and the casing when used continuously under the stipulated conditions.

As no high temperature sealant satisfies all the above conditions strictly, it is recommended that the use of these should be avoided as far as possible, restricting their use only to specific cases.

The glass fibre mat is incapable of maintaining its adhesion property at high temperature, and silicone sealant peels off readily if the temperature exceeds the rated temperature by just 10° to 20°. Again, the fusion resistant sealant becomes extremely brittle when heated.

Bonding agent made from rubber can be used for adhering ordinary gaskets to the filter.

(iv) Casing (Frame): Ordinarily, fire retardant exterior grade plywood, wood particle board and cadmium plated iron sheet are used as the filter casing material. The thickness is 3/4" in case of wood and 0.061" (#16 US gauge) in case of iron and should be able to withstand compressive force of more than 400 lb produced at the time of fitting in the filter. Mr. Burchsted personally thought the wooden casing to be the better. In case of particle board, the minimum density should be 45 lb/cu.ft.

(v) Gasket: The gasket constitutes one of the most important parts in the filter system. Results of tests[7] have confirmed that the air leakage rises above the permissible value if the thickness of the gasket is not uniform, or the corner has not been made properly, or adhession of the gasket with the filter is not very good.

If the gasket is made from a very hard substance, then bolts are to be tightened strongly for ensuring proper adhesion between the filter and the frame. Such overtightening of the bolt transmits very high stress on the filter leading to its breaking up. On the other hand, if the material of the gasket is too soft, then the bolts get loosened during use resulting in leakage of air.

Studies are in progress over the degree of hardness, quality of material and shape etc. for finding out the ideal gasket materials. The best material obtained so far is the closedcell neoprene sponge of ASTM-D 1056 grade SCE-43, with cut surface on both sides. This is ordinarily made in 3/4" x 1/4" size, and the corner can be pressed in notch or dove tail shape as shown in Fig. 8.

(4)-2-1-c. The other characteristics of the HEPA filter have been shown in Tables 4~8.

TABLE 4

Weight of the filters

Filter Size (in.)	Nominal Flow at 1 in. H_2O (cfm)	Approximate Weight (lb) of Filters with -	
		Wood Case	Steel Case
	Open-Face		
$8 \times 6 \times 3\frac{1}{16}$	25	2	3
$8 \times 8 \times 5\frac{7}{8}$	50	3.6	5.8
$12 \times 12 \times 5\frac{7}{8}$	125	4.8	7.3
$24 \times 24 \times 5\frac{7}{8}$	500	17	22
24 x 24 x 11½	1000	32	40

Contd.

1	2	3	4
	Enclosed		
8 x 8 with 2-in. Nipples	25	5	9
8 x 8 with 2-in. Nipples	50	7	10.5
12 x 12	125	17	20
24 x 24	500	64	72
24 x 24	1000	78	95

TABLE 5

Pressure resistance of open face HEPA filter*

Filter Dimensions (in.)		Overpressure (psig)		
		Test Value[a]	Recommended Design Limit**	
Face	Depth		With Face Guards	Without Face Guards
8 by 8	$3\frac{1}{16}$	36	3.1	2.0
8 by 8	$5\frac{7}{8}$	45	3.8	2.5
12 by 12	$5\frac{7}{8}$	36	3.1	2.0
24 by 24	$5\frac{7}{8}$	22	1.9	1.2
24 by 24	$11\frac{1}{2}$	32	2.7	1.8

*C.A. Burchsted, "Basic Requirements for H E P A Filters," Proceedings, 9th A E C Air Cleaning Conference, U S A E C Report C O N F-660904, Harvard Air Cleaning Laboratory, 1966.

[a] Clean filter with 4 by 4 mesh face guards on both faces.

**Dirty filters

1	2	3	4
	Enclosed		
8 x 8 with 2-in. Nipples	25	5	9
8 x 8 with 2-in. Nipples	50	7	10.5
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24 by 24	$11\frac{1}{2}$	32	2.7	1.8

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[a] Clean filter with 4 by 4 mesh face guards on both faces.

**Dirty filters

TABLE 6

Recommended temperature ceiling for fire proof HEPA filter in iron casing

Sealant Used	Temperature to which filter was exposed (°F)				
	Up to 10 min[a]	Up to 2 hr	Up to 48 hr	Up to 10 days	Indefinitely
HT-30-FR[b]	750	350	325	300	260
Z-743[c]	750	325	300	275	200
EC-2155[d]	750	250	220	200	200
Polyurethane[e]	750	325	300	275	230

a Some reduction in efficiency may occur after 5 min of exposure
b Goodyear
c Pittsburgh Plate Glass
d Minnesota Mining and Manufacturing (3M)
e Proprietary formulation of Flanders Filters, Inc.

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TABLE 7

Recommended temperature ceiling for fire proof HEPA filter in wood casing[a]

Frame Material	Temperature to which filter was exposed (°F)				
	Up to 10 min	Up to 2 hr	Up to 48 hr	Up to 10 Days[b]	Indefinitely[b]
3/4-in.-thick plywood[c]	750	300	275	200	180
3/4-in. wood particle board[cd]	750	300	250	180	180

a Subject to sealant limitations given in Table 3.4.
b Maximum temperature of 120°F where relative humidity is 75% or higher.
c Exterior grade fire-retardant treated.
d Minimum density = 45 lb/ft^3.

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TABLE 8

Cost index of HEPA filter

Casing Material	Separator Material				
	Untreated Asbestos	Aluminum Foil	Treated Asbestos[a]	Plastic	Stainless Steel
Wood	1.00	1.02	1.08	1.71	7.73
Carbon steel	1.13	1.16	1.22	1.89	-
Stainless steel	1.96	1.99	2.04	2.69	8.69

a Qualified for moisture and corrosion resistance in accordance with procedures established by the U S A E C.

OAK RIDGE NATIONAL LABORATORY

DESIGN, CONSTRUCTION, AND TESTING OF HIGH-EFFICIENCY AIR FILTRATION SYSTEMS FOR NUCLEAR APPLICATION

C. A. Burchsted and A. B. Fuller

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APPENDIX B. ESTIMATING FORMS

APPENDIX C. CARE AND HANDLING OF HEPA FILTERS

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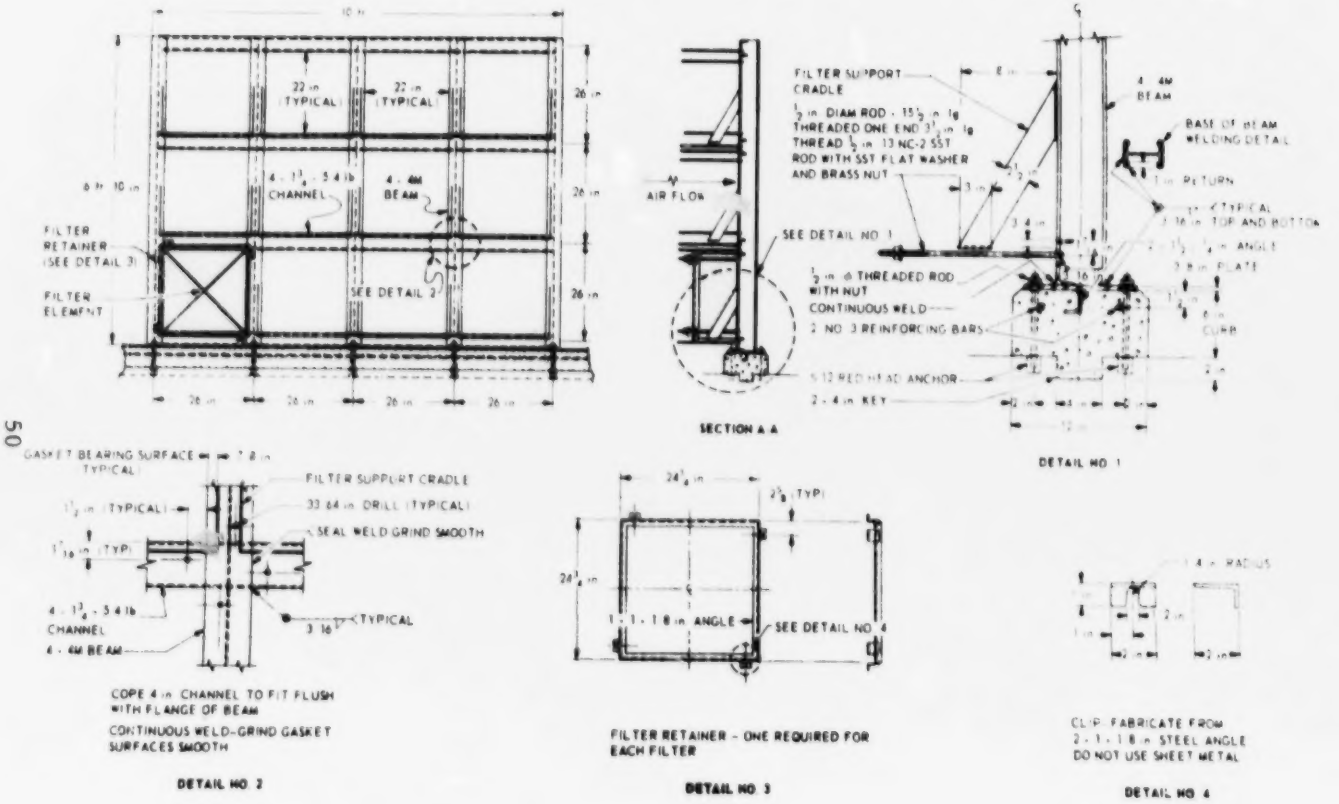
22 in (TYPICAL)
22 in (TYPICAL)
4 - 13/4 - 5.4 lb CHANNEL
4 - 4M BEAM
FILTER RETAINER (SEE DETAIL 3)
FILTER ELEMENT
SEE DETAIL 2
26 in
26 in
26 in
26 in
26 in
26 in
26 in
AIR FLOW
SEE DETAIL NO. 1
SECTION A A
FILTER SUPPORT CRADLE
1/2 in DIAM ROD - 15 1/2 in lg THREADED ONE END 3 1/2 in lg THREAD 1/2 in 13 NC-2 SST ROD WITH SST FLAT WASHER AND BRASS NUT
4 4M BEAM
BASE OF BEAM WELDING DETAIL
1 in RETURN
1/2 in TYPICAL 3/16 in TOP AND BOTTOM
2 - 1 1/2 - 1/4 in ANGLE
3/8 in PLATE
1/2 in ø THREADED ROD WITH NUT
CONTINUOUS WELD
2 NO. 3 REINFORCING BARS
5/12 RED HEAD ANCHOR
2 - 4 in KEY
CURB
DETAIL NO. 1
GASKET BEARING SURFACE TYPICAL
FILTER SUPPORT CRADLE
33/64 in DRILL (TYPICAL)
SEAL WELD GRIND SMOOTH
1/2 in (TYPICAL)
1/16 in (TYP)
4 - 13/4 - 5.4 lb CHANNEL
4 - 4M BEAM
3/16 TYPICAL
COPE 4 in CHANNEL TO FIT FLUSH WITH FLANGE OF BEAM
CONTINUOUS WELD-GRIND GASKET SURFACES SMOOTH
DETAIL NO. 2
24 1/4 in
2 3/8 (TYP)
24 1/4 in
1 - 1 - 1/8 in ANGLE
SEE DETAIL NO. 4
FILTER RETAINER - ONE REQUIRED FOR EACH FILTER
DETAIL NO. 3
1/4 in RADIUS
2 in
1 in
2 in
CLIP. FABRICATE FROM 2 - 1 - 1/8 in STEEL ANGLE DO NOT USE SHEET METAL
DETAIL NO. 4

Fig. 9. Details of the HEPA filter mounting frame.

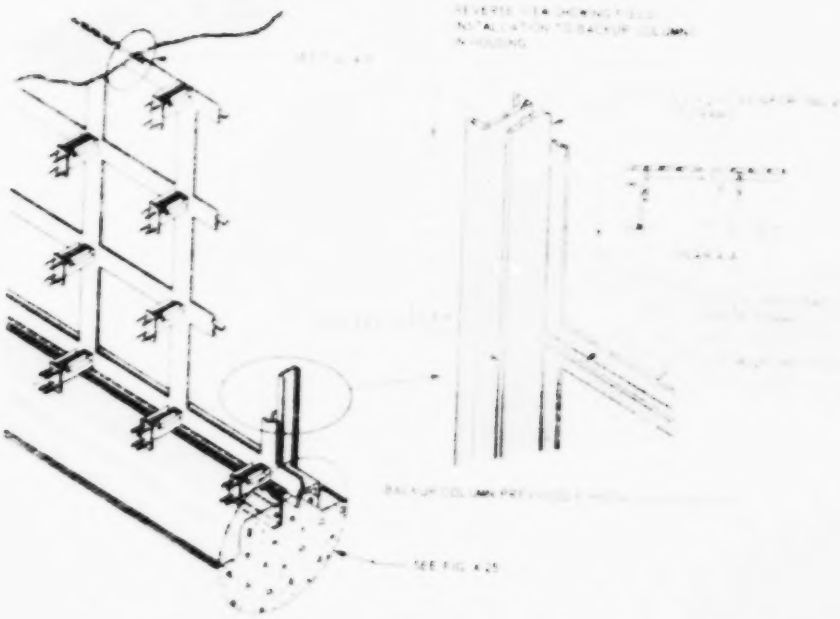

Fig. 10 HEPA filter mounting frame made from a single sheet

Fig. 11 Details and module dimension of HEPA filter mounting frame made from a single sheet

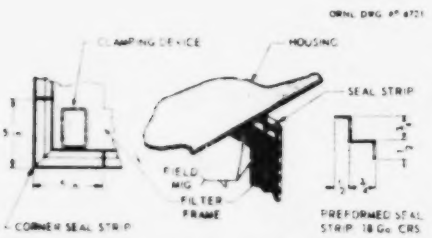

Fig. 12. Mounting frame and housing fitting section.

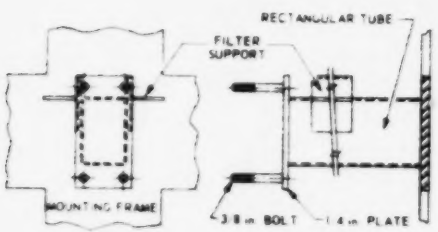

Fig. 13. Fittings and fixtures for mounting the filter.

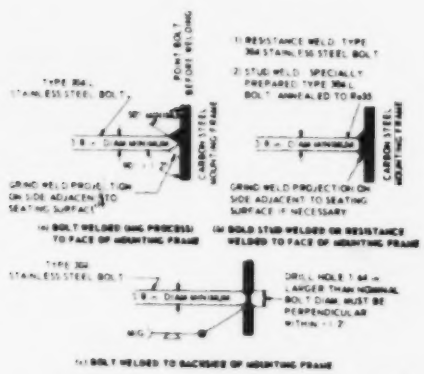
POINT BOLT BEFORE WELDING
CARBON STEEL MOUNTING FRAME
GRIND WELD PROJECTION ON SIDE ADJACENT TO SEATING SURFACE IF NECESSARY
DRILL HOLE 1/64 in. LARGER THAN NOMINAL BOLT DIAM. MUST BE PERPENDICULAR WITHIN ±1/2°

Fig. 14. Correct welding method of the fixing bolts

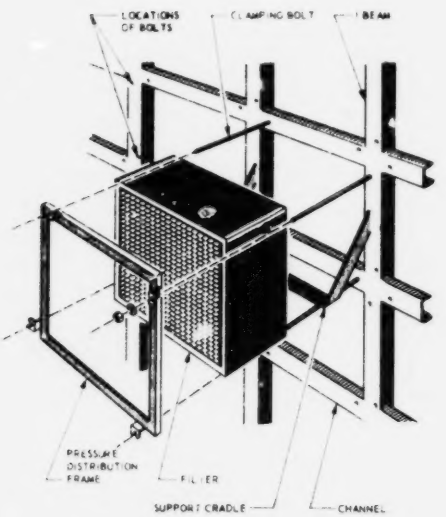

Fig. 15. Correct support of the filter.

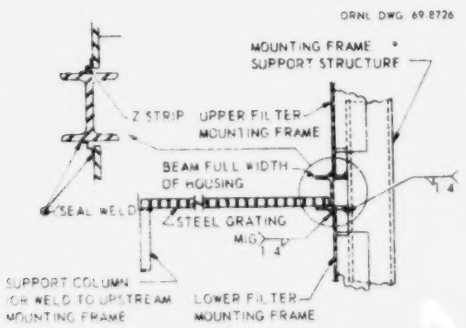

Fig. 16. Method of installing the service gallery when modular frame shown in Figs. 2 & 3 are used

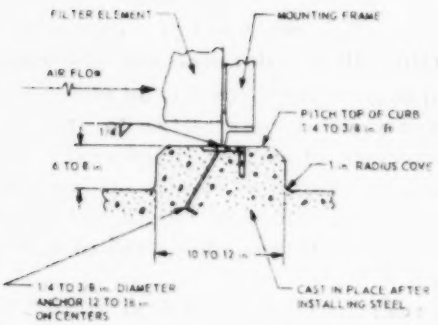

Fig. 17. Fixing the filter mounting frame on the concrete floor - welding is carried out from the side from which air blows in.

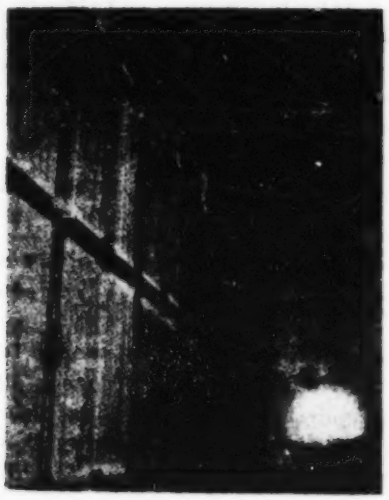

Photo 10. Bad example of fixing of the filter - use of common fittings and fixtures for the adjacent filters is bad here.

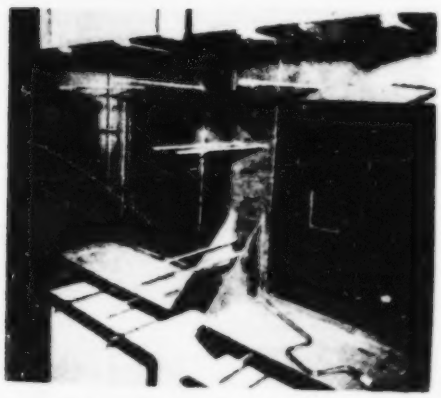

Photo 11. Improper support of the filter.

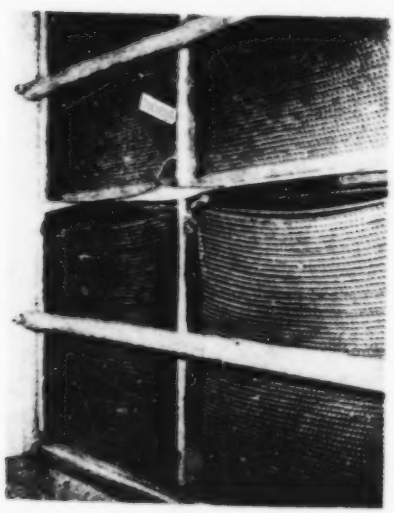

Photo 12. The filtering material has sagged by about 5.0 mm because of improper direction of placement of the filter.

4-3 AMERICAN AIR FILTER COMPANY, INC. GENERAL OFFICES

(1) Location: 215, Central Ave., Louisville, Ky. 40208, U.S.A.

(2) Date and time of visit: April 8, 1970, 10.00 A.M. to 5.00 P.M.

(3) A Brief Sketch of the Company Visited

The American Air Filter Co., Inc., (this will be abbreviated here as AAF from now onwards) was established in 1929 with the amalgamation of the three pioneers in the field of air filter and dust purification equipment, viz., Reed, Midwest and National.

The AAF has factories in Louisville and five other cities in the USA and has branches or agencies in all the principal cities of the country. Factories with technical collaboration with the AAF can be found in 14 countries including Japan, England and France, and has representations in more than 40 countries all over the world. Again, it has established a very efficient worldwide service network so that excellent AAF equipment can be procured without any difficulty.

Besides, the filters and dust collecting equipment, the AAF also concentrates on all types of machinery concerning air, and has set up an extremely efficient central engineering department capable of answering any question connected with air and the related fields.

The activities of the central engineering department are restricted not only to just designing and manufacturing the equipment, but have gone one step further inasmuch as it undertakes

the designing, manufacturing and installation of whole projects on turn-key basis. It is needless to say that it guarantees the overall performance of the plants it erects.

(4) Outline of the Visit

a. Sketch of the Visit

10.15: After the welcome address by Mr. B. Lawson, we went down to the basement and had a look at the Air Filter Exhibition Room where Dri pak Filter, Roll o pak Filter and Roll o tron Filter etc. were kept for display. Next, we saw the air conditioning room where these products were working in series through the glass window.

10.45: Visited the Plant No. 1 and Plant No. 3 of the Louisville factory. Both the plants were of about 4000 m^2 in area each, and accommodated a large number of latest precision machine tools. These were installed in a very rational fashion from the material receipt office and material receiving entrance to the final painting machine and shipment exit.

As will be stated later, all types of air filters, filter banks for atomic energy installations and industrial dust collectors are produced here. HEPA filters are manufactured at the Suma plant, and the glass fibre media are manufactured at Famco plant, both of which were not visited by us.

12.00: Went to the Louisville Executive Inn.

1.30: Explanation of the AAF set-up through slides.

1.50: Introduction to various types of air filters along with the equipment with which they are used through slides and catalogues by Mr. J. May.

2.50: Explanation of the working of the clean room system through slides and catalogues by Mr. R. Pond.

3.50: Introduction to the dust collectors along with the equipment with which they are used through slides and catalogues by Mr. G.C. Rodgers.

4.45 - 5.00: Discussion

b. On Clean Room

The AAF clean room system has been so well designed that appropriate modification can be effected whenever some customer desires it. Basically, the AAF designs the clean rooms as class 10,000 clean room, and these are converted into class 100 clean rooms just by installing hoods. Again, there is also a provision for creation of class 100 clean room sectionally. There are other methods of creation of class 100 clean room also, for example, by raising the floor, or by switching over the vertical laminar flow system keeping all other things untouched. Control of temperature and humidity can be carried out arbitrarily depending upon the necessity.

b-1. Modifying Class 10,000 Module by using Class 100 Hood (Fig. 1)

i) The size of the hood required for critical class 100 operation is determined.

ii) In case of necessity, AAF air handling capacity is supplemented to be used as the air supply hood.

iii) AAF filter module is fitted and connected to the air supply control system.

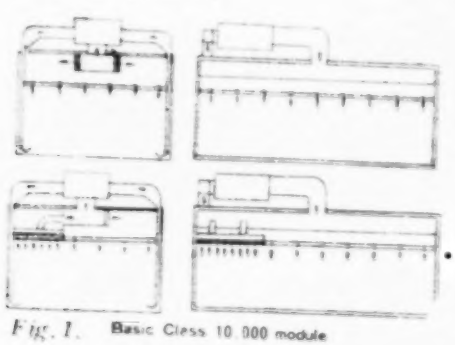

Fig. 1. Basic Class 10,000 module

iv) Proper adjustment and balancing with the system is carried out and then operated.

b-2 Improving by Instituting Local Class 100 Control in the Class 10,000 Module (Fig. 2)

i) The size of the class 100 zone required for the work is determined.

ii) Keeping in line with the enhanced demand, the capacity of the already existing AAF air conditioner system is raised appropriately.

iii) AAF clean room fan module is installed.

iv) AAF Bevel-seal HEPA ceiling is installed.

v) Proper adjustment and balancing with the system is carried out and then operated.

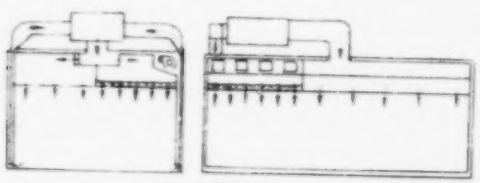

Fig. 2.

b-3. Renovating the Class 10,000 Module into Two Environment Control Rooms (Fig. 3)

i) The room is partitioned with AAF paper seal panel.

ii) AAF air conditioner module is supplemented depending upon the modified demands of the new zone.

iii) Filter and control devices are installed for the new zone.

iv) Adjustment and balancing are carried out to marry the old and the new systems and then operated. *Fig. 3*

b-4. Class 10,000 Module Converted into Class 100 Laminar Flow System (Fig. 4)

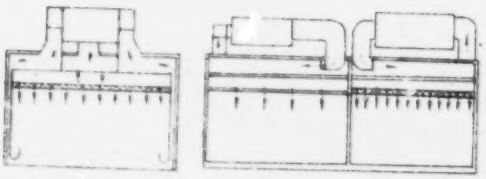

Fig. 3.

i) The ceiling return air system wall and the piping system are dismantled.

ii) The AAF fan module is converted into installed hollow wall.

iii) The AAF air conditioning system is upgraded.

iv) The floor is raised depending upon the requirement.

v) The system is adjusted and balanced, and then operated.

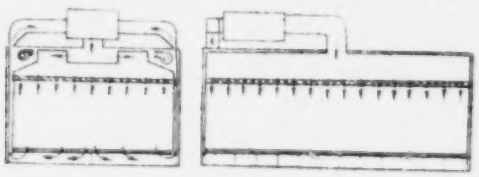

Fig. 4.

b-5. AAF Paper Seal Panel System (Fig. 5)

The AAF panel system consists of insulated honey comb panel of approved strength; and it is a very simple system by which perfect type wall can be erected for control of environment using vapor-proof joints. This joint can be removed freely either for changing the arrangement of the room or for enlarging its capacity.

As the panels are very tough, it is possible to use these successfully in open for the first time, or to use these as the environment control wall. As simple and light joint is used here, it is very economic as well as easy to erect wherever required.

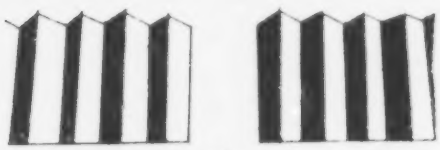

Fig. 5.

b-6. Characteristic Features of the Construction

i) There is no danger of the paper getting soaked as air tight sealing has been done with batten which is operated with the help of spline which is non-combustible.

ii) As the system is of perfectly free standing type, there is no necessity to use any reinforcing material or fittings and fixtures.

iii) As a special joining method has been adopted here, the size does not pose a restricting factor.

iv) The panel is 3" thick, the insulation coefficient U is 0.18, and it is excellent in quality.

v) The surface of the panel is provided with 25 or 24 gauge steel finish, or 0.050" aluminum finish or enboma finish.

vi) The outer face is finished with silicon alkali enamel.

b-7. AAF Bevel Seal Supporting Implements (Fig. 6)

The support consists of aluminum T-section assembly prepared by precision machining and electrolysis. This especially developed T is of special inclined stair-shape, and fits in tightly with the filter gasket for sealing the space in between the filter cell side and the support system. It does not permit any leakage.

In the case of typical AAF plenum type vertical laminar flow ceiling, the entire clean room area is covered with the HEPA filter, and no space is kept aside for illumination lamps as in the case of flush mounted type.

As the fixed wiring for lights which takes a large volume of space is eliminated in the AAF system, the area of the filter medium increases by 25～30%, and the generation of large draft under the light source is eliminated.

Hence, the surface speed of air decreases which means longer life of filter for the user and lesser wear and tear loss for the filter bank.

Fig. 6.

b-8. Constructional Characteristics

i) Reliable gasket sealing is possible by the bevel seal.

ii) As the working starts from the lower side, exchange of filter is very easy.

iii) The gasket can be compressed to appropriate degree with the help of clamp provided with spring.

iv) The filter clamp is provided with protective gride so that it can be removed without any difficulty at the time of monitoring or exchanging filter.

c. Other Questions Related to Contamination Control

This company also makes diverse types of equipment for contamination control, which were explained through slides. The sum up has been shown in the tables given below.

TABLE IIa)

Different types of filters

Name	Mechanism	Uses
Roll o tron	It is a dust collecting polar plate, and the dust collected electrically on the plate is captured by the glass medium of the stridge section and rolled automatically. (Colorimetry: 90%).	Used for the removal of superfine dust of size below 1μ but upto 0.01μ and for sterilization. For example, used in ordinary air conditioning of the buildings, in exchanging air in the lens, film, vacuum tube, and transistor factories, in chemical and fermentation plants, in sterilization in the hospitals, operation theatres, and laboratories, and in removing fumes in the nylon plants, etc.
Electro pack	Similar to the roll o tron, but a higher degree of cleaning is achieved here by using dry pack in the stridge section. (Colorimetry: 97%).	
Electro matick	The fine dust of the air charged in the ionization section is captured on the dust collecting polar plate, which is rotated with the electricity switched on, thus effecting automatic cleaning. (Colorimetry: 85~90%).	
Roll o matick	A glass fibre mat called "roll o mat" which can expand and contract freely has been used here. It rolls automatically. (Gravimetry: 85%)	It is a typical air filter with extensive use in air conditioning the buildings, and cleaning air in various types of factories.

Cont'd

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1	2	3
Roll o pak	It is a dri pak prefilter, and is used together with roll o matick. The two form one unit. (Colorimetry: 80～85%) (Colorimetry: 93～97%).	Most suited in the air exchanging and air conditioning systems of the factories and buildings where especially high cleanliness is needed. Large volume of air can be processed.
Auto air mat	Special type filter paper is used here, and the dust is removed by rolling the mat using the principle of air resistance. (Gravimetry: 90%)	Used for removing lint in the spinning mills, ink mist in the printing works, and special type dust.
Multi duty	The filter is composed of a number of metallic penals put together. Formation of oil film on the penal surface and cleaning of the dust collected thereon are carried out automatically. (Gravimetry: 85%)	Used in obtaining air for air cooling (for air cooling the rolling motors in iron and steel mills) for removing dust from air in the manufacturing process, and for preparing air to be used as raw material etc. It is also suitable for large scale cleaning of air.
Dri pak	It uses micro glass fibre mat as the filtering medium. It is a suction type cartridge filter (Colorimetry: 50 - 55%) (" 80 - 85%) (" 93 - 97%).	Most suited for factories and buildings requiring air of high degree of cleanliness, as well as for highly clean air conditioning system.

Contd

1	2	3
Astro cell	(DOP 99.97)	
Bio Cell	Glass fibre has been used as the filtering medium here. Corrugated separator has been put in between the pleat shaped filtering material for enlarging the filtering area and increasing the life. (DOP 95%)	Used for removing radioactive dust, as well as in aseptic rooms and the like, where ultra high degree of pure air is needed.
Deep bed	It is a pocket sized unit using micro glass fibre mat as the filtering material (filter down). (Colorimetry: 85%)	Precision machine tool factory and others
PL air filter	Filtration is carried out by using special type filtering material. (Gravimetry: 92%).	Used for air conditioning in beer and various other factories.
HV filter Grease filter	These are units formed by piling [illegible] of triangular drill-shaped wire screen. Sticking oil is added. (Gravimetry: 80%).	Air cleaners for vehicles. Used for removing oil mist and vapor in the kitchen as well.

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TABLE 1(b)

Various types of dust collectors

		Name	Mechanism	Uses
CENTRIFUGAL TYPE	WET TYPE	Lot Klon N	When the air containing dust passes through a S-shaped impeller provided on the water surface, the effective contact of dust with water is increased by increasing the inertia of dust by increasing the air speed. Above 1μ: 98%	1) Used in transportation, crushing, sieving, and mixing of raw material as well as in storing. 2) Used to purify the exhaust gas in fusion furnaces, roasting ovens, kilns, drier and cooler. 3) Used for removing dust and purifying air in the pits. 4) Used for eliminating mist and vapor produced during acid bath, electroplating and painting.
		Lot Klon R	Wet-type cyclone principle has been adopted here. The main body consists of a vertically arranged tube with overlapping double inlet. As the air containing dust whirls down the tube, the air and dust get separated. This effect is enhanced all the more by supplying water from the top. Above 5μ: 98%.	1) Used for cleaning the exhaust gas from driers and industrial ceramic kilns. 2) Used in casting plants (shake out, sand blast etc.). 3) Used for removing dust in coal and ore mines. 4) Used by the manufacturers of fertilizers and sound-proof tiles etc.

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1	2	3	4
CENTRIFUGAL TYPE — WET TYPE	Lot Klon W	It is a compact centrifugal type model where the high performance dust collection section (impeller section) can also function as an exhaust. Water spray is provided near the entrance to form a film of water on the impeller surface. As dust dashes against this water film, it gets removed. Above 5μ: 98%.	1) Used in transportation, crushing, sieving, mixing and storing of raw material. 2) Used in casting plants (Shake out, tumbling mill etc.) 3) Used in fertilizer factory (drier, cooler, removing fume during ammonia synthesis, etc. Cycoil M is recommended to be used as the tail end device for increasing efficiency). 4) Collecting flue in boilers using heavy oil. 5) Used for exchanging air in the kitchen and removing the oil vapor.
CENTRIFUGAL TYPE — DRY TYPE	Lot Klon D	This model is identical to Lot Klon W, with the exception that the principle of mechanical centrifuging has been adopted here. For this the shape of the impeller has been modified. Above 5μ: 85%.	1) Used in processing of metal grinding, buffing, and cutting the casts). 2) Wood industry (sawing, sand paper polishing) 3) Rubber industry (grinding, buffing). 4) Removing dust at the time of processing resin, leather etc.

Contd.

1	2	3	4
DRY TYPE	Ama Klon	It is a multi-klon of axial flow type with a special design. About 10-20% of the air containing the separated dust is further sent to a separate separation tube by force where even the fine dust is removed. Above 5μ: 93%.	1) Used in coal fired and wood fired boilers 2) Used in transportation, crushing, sieving, mixing and storing of raw materials. 3) Used in cupola exhaust gas. 4) Used in asphalt plant (reinforcing material drier), coal drier, barium sulfide drier. 5) Casting mills (Shake out, sand treatment).
WASHING TYPE	Cycoil M	Gas containing mist vapor of acid or alkali is allowed to come in contact with the washing medium (mainly water is used) inside a special structure (made from polyethylene) filled with certain thing, when the mist vapor gets removed.	Used for removing mist vapor of acid or alkali contained in the gas. Used for cleaning the exhaust gas from acid bath and electroplating, recovering sulfuric acid from viscose solvents, cleaning exhaust gas of chemical laboratories and testing rooms.
	Kinpakta	It is a venturi scrubber with a specially designed water supply section. Special type reflector plate has been provided in the water jet mechanism of the slot section which ensures complete enveloping of the cross section by the water drops. Thus, even the fine dusts are removed with very high efficiency. Above 0.5μ: above 99%.	It is suited for high efficiency removal of fine dusts. Used in rotating furnace, electric furnace, hot scarfer, high temperature furnace and casting bed etc.

AMERICAN AIR FILTER COMPANY

1	2	3	4
FILTERING TYPE	Ama jet	It is a reverse jet type bag filter. The bag is usually made from wool felt. However, other materials like chemical fibres cotton etc. can also be used depending upon its use. Above 0.3μ: above 99%.	It is used for high efficiency removal of fine dust. 1) Used in transportation, crushing and mixture of cement, powdered food articles and tobacco carbon black etc. 2) Used for purifying air to be used as the raw material. 3) Used in spray milk drier, PVC drier. 4) Used while processing leather asphalt, graphite, barium etc.
	Ama therm	It is a bag filter for removing dust from high temperature gas. The bag is cleaned by precision dumper operation. Above 0.5μ: above 99%.	Used for high efficiency removal of fine dust and foam from high temperature exhaust gas from all types of furnaces. Used in electric furnace, cupola, cement kiln, roasting furnace, oxygen rotation furnace, etc.
	Ama tube	It is a bag filter employing the principle of shaking. At the time of shaking, the dumper is closed and the bag is cleaned. Above 0.5μ: above 99%.	It is suited for the recovery or removal of diverse types of dusts.

1	2	3	4
FILTERING TYPE	Dust attraction	Here filtration is carried out with the help of a pocket sized material which can be replaced very easily. The dust adhering to the filter surface is removed with the help of vibrator. Depending upon the shape and state of the dust, cloth, air mat and glass fibre etc. can be used. Above 0.5μ: above 99%.	It is well suited for removing fibrous dust or fine granular dust.
	Oil mist collector	It is a package type model based on the principle of filtering with the help of glass fibre bag. The fan, motor, filtering material, drain box etc. are all accommodated inside the package. Just installing the package near the source of the dust serves the purpose.	It is used for removing oil mist, smoke, foam etc. produced during machining. After filtering, the air can be recycled to the place of work. It can be used near the lathes, milling machines, automatic screw cutters, and drilling machines et It can also be used near the bearing grinder, die cast machine etc. for removing mist at the time of forced circulation. It is also used for removing mist produced by cold drawing machines, etc.

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Persons Interviewed

F. E. O'Callaghan	Managing Director, AAF International
R. Lawson	Managing Director, AAF International
E. Hubbuch	Application Engineer, AAF International
J. May	Technical Director, Air Filter Div., AAF, Inc.
R. Pond	Project Manager, Clean Room Systems, Air Filter Div., AAF, Inc.
G. C. Rodgers	Specialist, Planning and Marketing Dept., Air Pollution Products, AAF, Inc.

(Reporter: Sachio Yoshikawa)

4-4 UNIVAC WESTERN COMPUTER CENTER

(1) Location: Data Processing Division, 2276 Highcrest Drive, Roseville, Minn., 55113.

(2) Date and time of visit: April 10, 1970. 10 A.M. to 3.00 P.M.

(3) Brief sketch of the UNIVAC

UNIVAC is a leading computer manufacturing company of the U.S.A. and is manufacturing large sized real time computers like model 1108 etc. There are eight plants in all in this center, and we went round only two of them, Plant No. 1 and Plant No. 4. About ten thousand persons are employed in this center. A list of the plants is given below.

No. 1: Division Headquarters, area: 244,400 sq ft; (2750 West 7th Blvd, St. Paul) Advanced Research, Systems Engineering, Thin-film Memory Manufacturing, Military Computer Center.

No. 2: Reliability Laboratory; area: 164,640 sqft. Environmental Testing, Navy Computer Center, 490 Computer Center.

No. 3: Computer Assembly and Test; area: 123,900 sqft. Printed Circuit Manufacturing, Core Matrix Manufacturing.

No. 4: Commercial Data Processing; area: 385,640 sqft. Engineer and Manufacturing.

No. 5: Product Line Engineering; area: 172,000 sqft. System Engineering, Metal Fabrication.

No. 6: Field Engineering; area: 51,200 sqft.
Purchasing, Accounting.

No. 7 & No. 8: Details of the plants are not known.

(4) Outline of the Visit

A. Sketch of the Visit

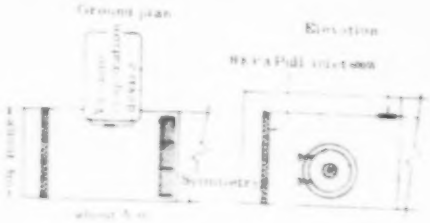
In the very beginning we heard the views on clean room from the people actually working in the clean rooms in the conference hall of the UNIVAC. Following this we went to see the Plant No. 1. In the afternoon we visited the Plant No. 4.

In Plant No. 1 we saw the clean room where vacuum evaporation process is carried out, the clean bench of the thin film memory manufacturing device, the horizontal laminar flow clean room where various types of works are carried out and the 1108 computer room. In Plant No. 4 we saw the clean rooms where the gauges were kept.

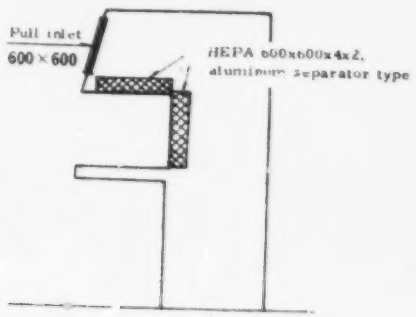
B. On the Clean Rooms

1) Clean Rooms of Plant No. 1

(i) Clean Room of the Vacuum Evaporation Device: Only the front section of the vacuum evaporation device has been accommodated inside the clean room. The inlet for bringing in the parts has been designed carefully so that the door attached there can be opened or closed for inside the clean room. Class 100 HEPA filter manufactured by Farr Co. has been used. The surface air speed is about 100 ft/min.



(ii) Clean Bench of the Thin Memory Manufacturing Device: There were five clean benches and people were working at them after putting on dust proof dress, cap, and rubber gloves.



(iii) 10,000 Class Horizontal Laminar Flow Clean Room: This is not in use as clean room at present, although it was formerly used as such. It is still fit for use, but has been closed down as a clean room since its running involves high expenditure producing very little return. However, it is in use for some other purpose, and people were working there busily. A section of the building has, however, been partitioned off with panel for use as clean room. The ceiling here is also of panel.

(iv) 1180 Computer Room: In this room there are four push and pulls per bay, with push angular anemo and pull punching. The room is provided with smoke detector.

The floor is of ordinary type, and not the aluminum assembled type access floor commonly used at present. Here, probably, the pull is from below. The stipulated temperature of this room is 70°F (21.1°C). The air conditioner is fitted above the room, and the cooling machine is a 100 RTmodel.

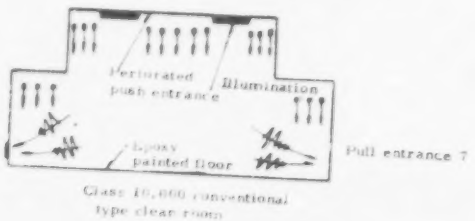
2) Clean Rooms of Plant No. 4

The gauges are accommodated in two rooms, Room A and Room B, and we visited both of them. A soft mat of the size 600 x 900 (synthetic resin fibre + pig's hair) is placed on the floor of the lobby at the entrance of the plant for removing the dust from the shoes. The brand name is HEUGAFROR.

Room A: Temperature condition: 68°F (20.0°C) ± 1/4 °F(0.14°C)
Humidity condition: 35 ~ 40% RH
Number of times the air is replaced: 40 times
Illumination: 100 ft candle
Installed cooling machine: 10RT
Mode of air conditioning: Direct expanding + reheat provided with preheat (steam)

Room B: Temperature condition:68°F(20.0 °C) + 1/10°F (0.056 °C)
Humidity condition: 35~40% RH
Number of times the air is replaced: 60 times
Installed cooling machine: 4 RT
Mode of air conditioning: Direct expanding + reheat provided with preheat (electricity)

Armstrong system has been adopted for adding the humidity. The duct is based on the Smakner process.



Class 10,000 conventional type clean room

C. Present Views of UNIVAC on the Clean Room

So far as the computers are concerned, clean rooms with especially high level of purity are not a must. Although, initially clean rooms with high level of cleanliness were built, yet experience has shown that the level can be somewhat lower without any adverse effect. So at present clean rooms with lower level of cleanliness and clean benches are used. The construction cost of clean room with high cleanliness level is very high which gets reflected in the cost of the products. It is better to economize to the level where it will not affect the quality of the products.

As far as possible clean room will not be erected in future for reducing cost of the computers.

It is a costly proposition to get the dress and the shoes changed.

Grade will depend upon the experience. It will be slackened slowly, but will be modified when it becomes bad.

Inspection of the state of cleanliness of the clean room is carried out at different spots, and that also not continuously.

There is no uniform standard regarding the number and size of the particles. These vary depending upon the nature of the work.

The fume of oil is especially harmful.

(5) Persons Interviewed

UNIVAC Co.: Jack E. Ross, Manager, Plant Maintenance
UNIVAC Japan: Mr. Okada

(Reporter: Sasaki)

4-5 SANDIA LABORATORIES

(1) Location: Sandia Corporation, Albuquerque, New Mexico, 87115, U.S.A.

(2) Date and time of visit: April 13, 1970. 10.00 A.M. to 3.00 P.M.

(3) Brief Sketch of the Sandia Laboratories:

The Sandia Corporation has been established with the sole objective of developing nuclear weapons, and it is under the control of the US government. The first laminar flow clean room in the world was built here.

(4) Outline of the Visit

(4)-1. Sketch of the Visit: We visited a number of clean rooms here and heard talks about recent studies carried out here on contamination control.

(4)-2. On the Clean Rooms

(4)-2-1. Wall to Floor Laminar Flow Clean Room: The first laminar flow clean room in the world was built here under the guidance of Mr. Whitfield. It is known as 'wall to floor laminar flow clean room' and while seeing it in minute detail we heard the explanation directly from Mr. Whitfield. A rough sectional diagram of this clean room has been shown in Fig. 1.

It is an indoor assembly type construction using stainless steel sheets in the floor, walls and ceiling. Of course, Mr. Whitfield added that stainless steel sheets are not absolutely essential. He also said that there is an outdoor assembly type model as well, but we could not see it.

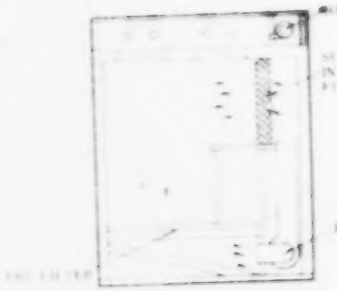


Fig. 1. Wall to floor laminar flow room.

The environmental conditions and dimensions of this clean room are as follows:

Environmental conditions:

Contamination level :	100
Temperature:	75°F ± 2°F
Relative humidity:	20% average; range is 5 ~ 30%
Pressure:	0.05" W.G.
Light intensity:	125 f.c.

Dimensions:

Without air shower:	8'W x 10'L x 9'H
With air shower:	8'W x 17'L x 9'H

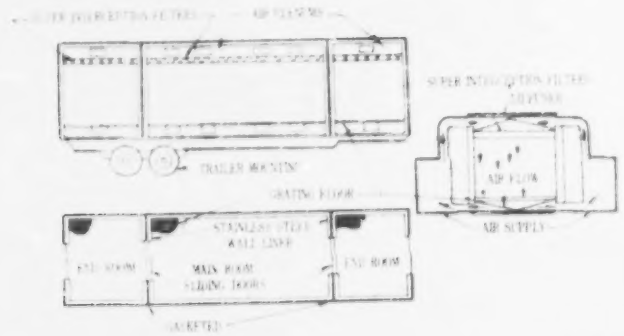


Fig. 2. 3-Compartment vertical laminar flow trailer mounted clean room.

(4)-2-2. 3-Compartment Vertical Laminar Flow Trailer-Mounted Clean Room: As shown in Fig. 2, it is a down flow-type laminar flow clean room made entirely out of stainless steel. It can be mounted on trailer and carried anywhere just by disconnecting the air handling system.

Inside this clean room Mr. Whitfield demonstrated the process of self-clean down by the laminar flow using tobacco smoke. The self-clean down performance was indeed remarkable.

Environmental Conditions:

Contamination level:	Class 100
Temperature:	75°F
Relative humidity:	20%
Pressure:	0.05" W.G.
Light intensity:	-

(4)-3. On the Present Situation

Studies are in progress at present on the inspection of the clean room from the angle of contamination control.

(4)-3-1. Automatic Dust Counter

Studies are in progress at present for developing dust counters which will be capable of coping with much higher sampling flow rate compared to the dust counters currently in use. The maximum capacity of the present dust counters is in the zone of 1~2 c.f./min, and the target is the capacity of 20 c.f./min. The prospect of using laser for the purpose is also under active consideration.

(4)-3-2. Vacuum Probe Microbiological Sampler

It has been devised for collecting microbes from the surface of a large area with low degree of contamination. The diagram of the device has been shown in Fig. 3 and 4.

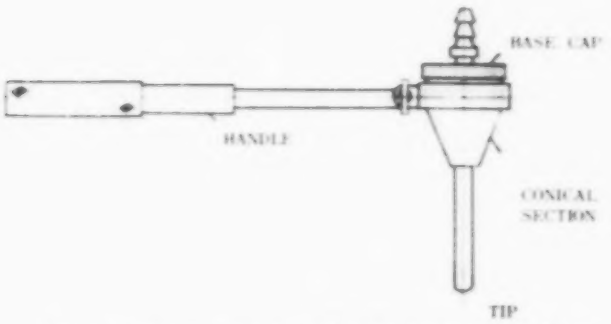


Fig. 3. Vacuum probe microbiological sampler.

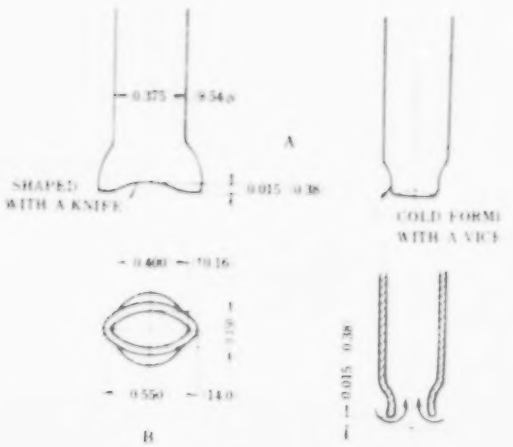


Fig. 4. Tip of vacuum probe.

The characteristic feature of this probe lies in the shape and dimensions of the suction tip. The tip has been planned so carefully that the air flowing through the tip reaches the speed of sound. Again, the tip also can produce ultra-sonic waves. The function of the ultra-sonic waves is to lift up the fine substances adhering to the surface of things.

(4)-3-3. Studies on Fallout

Studies are in progress for investigating the fallout of the microbes. Fallout from the angle of microbiology is also under study.

B1-4. Impression

The sampling flow rate of the conventional type dust counter is too low to determine the dust concentration in high class clean room and clean bench. Because of this defect it is rather impossible to assess the dust concentration speedily. Of course, dust counters with relatively high sampling flow rate (1 c.f/min) have been marketed recently. Even then efforts are in progress for developing counters with tens of times higher sampling flow rate. It is indeed a laudable enterprise.

The strong interest shown on fallout by our hosts came as a lesson to us as we are more prone to be swayed away by the air borne particles which can be counted quite easily and automatically.

(5) Persons interviewed

D. M. Garst, H. D. Svinsky, W. J. Whitfield.

(Reporter: Noboru Yoshimura)

4-6 BOEING COMPANY

(1) Location: The Boeing Company, P.O. Box 3707, Seattle, Washington, 98124.

(2) Brief Sketch of the Company

Although the Boeing is a famous name in the field of aeronautics, yet it has played a significant role in the space development program as well. We saw here the clean rooms, thermostatic rooms and manufacturing facilities in the following establishments of the company located at Seattle.

1) Document D2-23391 "Conventional Clean Room" in the Missile Production Center of the Aerospace Division.

2) Lunar Orbiter Final Assembly Room (Horizontal Laminar Flow Type Clean Room) of the above.

3) Quality Control Rooms (Room No. 2-4747 and 2-4741) of the above.

4) Metrology Laboratory (Room No. A-3, A-5, B-3, and air conditioning machine room).

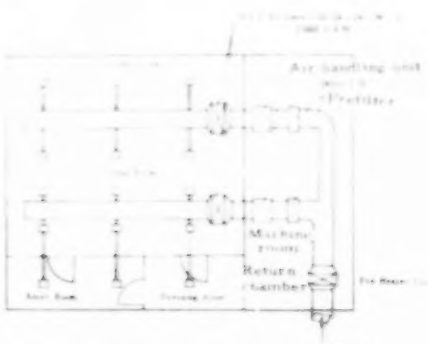
5) Final Assembly Plant of Boeing 747.

We had lunch and discussion with the persons escorting us after seeing the first four places, and then saw the fifth and last place in the afternoon. The last place we saw will not feature here as no clean room is involved here.

(3) Outline of the Visit

(3)-1. Aero-Space Division: Document D2-23391, Conventional Clean Room

It is the cleaning room of the parts received from outside and of the parts shipped outside, and consists of a front room and a main room. It is a conventional type clean room conforming to class 100,000 of US Federal Specification No. 209a. Again, clean benches are provided whenever the nature of the work requires these. At the time of designing the room provision was made for six persons to work here. However, only two persons normally work here at present. The other notings made regarding the facilities etc. are as follows.



Capacity of the room	12,000 feet³
Class	100,000
Pressure inside the room	0.05"
Illumination	2,000 F.C.
Temperature	72°
Humidity	45%
No. of times the air is circulated	about 34 times/Hr

Fig. 1-1. Rough sketch of document D2-23391 conventional clean room.

1) The room is of modular type, and can be changed freely.

2) The floor and the walls have been given an epoxy resin finish, and the joints have been covered with tape.

3) We were told that the mats are more effective than the shoe cleaners for eliminating the danger of dust being carried in by the shoes.

4) The exhaust gas is drawn from the periphery of the ultrasonic cleaning bath.

5) The degree of contamination of the room is monitered with the help of optical method and the findings are recorded in the chart sheet provided for the purpose.

Flow Chart - Conventional Clean Room:

1) The degree of cleanliness of the articles cleaned is determined by finding out the state of contamination of the liquid used for cleaning.

2) Pure water is used as the water for cleaning. 50,000Ω is its minimum specification, the pH is 6~8.

3) Two plastic film bags one placed inside the other are used in sealing the parts. The inner bag is pinkish in color and is provided with a special type statical electricity resistant film. The opening or closing of the film is carried out inside the clean room. The parts shipped out are further packed inside the front room prior to shipping.

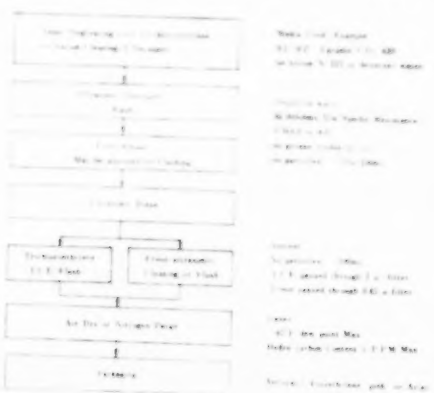


Fig. 1-2

4) No space vehicle is cleared which carries a single dust of metallic origin of the size above 5μ. It should also be absolutely free from dusts of other type above the size 20 μ.

(3)-2. Lunar Orbiter Final Assembly Room

The clean room here is of horizontal laminar flow type, and as the name indicates it is used for the final assembly and check-up of the lunar orbiter. The ground plan of the room has been shown in Fig.2-1, and the cross section has been shown in Fig.2-2. This clean room appears to be the same as that appearing on page 220 of the book "Clean Rooms of the World - Case Book of 200 Clean Rooms" published by Mr. Austin.

Class of cleanliness:	100 in the vicinity of the filter bank
Capacity of the room:	50F x 50F x 12F
Temperature:	72°F ± 2°F
Speed of air:	100 FPM
Illumination:	100 F.C.
Humidity:	45 % ± 5 %
Construction cost:	$ 80,000
Number of times the air circulated:	600 times/Mr

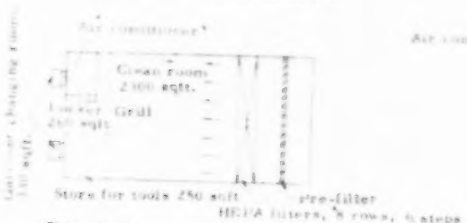


Fig. 2-1

Fig. 2-2

The other notings made regarding the facilities etc. are given below.

1) Two air conditioners each with 15 RT/Hr capacity have been installed of which one serves as the reserve.

2) The pre-filter uses 1" thick fibreglass filter.

3) 24 units of air blowers, each with 1 1/2 HP capacity, have been installed.

4) About 10% of the total air circulated is channelized through the air conditioner. The proportion of the outside air introduced is about 1% of the total volume of air circulated.

5) The walls are made up of ordinary building materials.

6) HEPA filters with 99.99% (DOP) capacity have been used. 24 rows and 6 steps of 24" size filters have been used.

7) Steam is used in heating the air conditioners.

8) The clean room has been designed in July 1965.

Various problems concerning maintenance

1) A question was asked whether there are troubles in the gasket of the filter bank or not? The reply was that indeed there are troubles, and hence the gasket is checked periodically and the necessary repairs are carried out with the seal. So checking does not become necessary on the room side. The gasket used is made from Neoprene rubber.

2) The dust counters of Royco Co. are not used here for determining the state of contamination of the room. The dust above 5μ size is monitered optically and the findings are noted on the designated card hanging at the entrance of the room.

(3)-3. Quality Control Rooms

A. Contamination Control Room No. 2-4747: A part of the factory accommodates a number of rooms where various types of tests for quality control are carried out. The Contamination Control Room in this complex moniters the state of contamination of the air circulating in the above clean rooms. It also checks the liquids used at various steps of cleaning. It is a conventional type clean room and all the necessary works are carried out on clean benches.

B. Room No. 2-4741: It is a conventional type clean room accommodating various types of equipment like mass analysis equipment, gas chromatography facilities, infrared analyzer and X-ray spectrometer etc.

(1)-4. Metrology Laboratory

It is one of the constituent parts of the Central Research Institute of the Boeing Co. The floor plan of the laboratory has been shown in Fig. 4-1; and excluding the rooms accommodating the offices, all other rooms are conventional type clean rooms. However, it appeared that they were not very particular about the degree of cleanliness. The clean room section of this laboratory has been partly described by Mr. Austin on page 349 of his book "Clean Rooms of the World - Case Book of 200 Clean Rooms". The degree of cleanliness of these clean rooms conforms to Class S of the specifications laid down by the Boeing Co., and is somewhat inferior to Class 100,000 of the US Federal specifications.

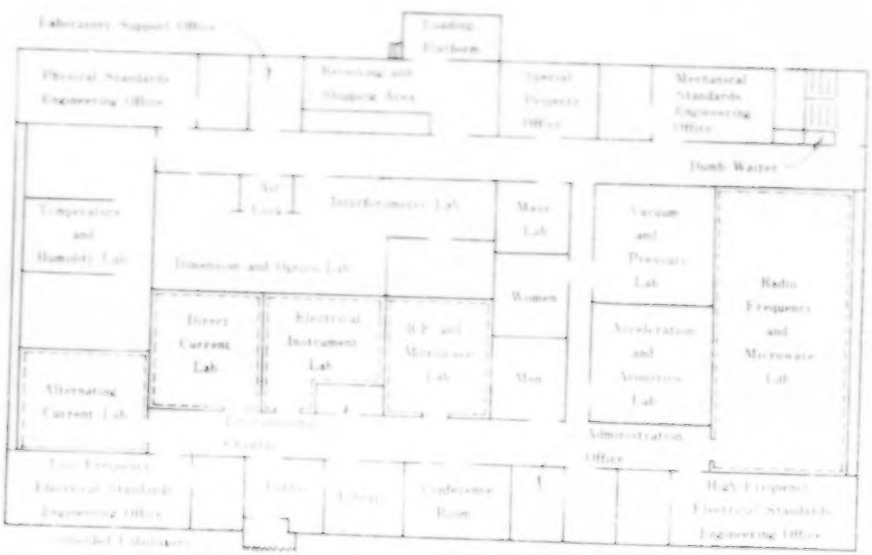


Fig. 4-1 Floor plan of laboratories

The floor plan shown in Fig. 4-1 pertains to the ground floor of the laboratory; and we saw the Direct Current Laboratory (Room No. A-3), Electrical Instrument Laboratory (Room No. A-5), Dimension and Optics Laboratory (Room No. B-3), and the air conditioning plant located in the basement. From the floor plan it will be seen that the rooms accommodating the offices are located on the outer periphery of the building in order to reduce the effect of temperature of the atmosphere on the thermostatic rooms.

(3)-4-1. Room No. A-3, Direct Current Laboratory

As shown in Fig. 4-2, the whole of the ceiling has been used as the perforated air inlet and monitoring of temperature is carried out with the help of a sampling header the construction of which has been shown in Fig. 4-3. A temperature detecting thermister is accommodated inside the header, and it controls the electrical heater for reheating with the help of an Electro-O-Volt of Honeywell Co. Temperature condition: $73^{o} \pm 1^{o}F$; humidity condition: $50\% \pm 5\%$; pressure difference: 0.05" Aq (Magnehelic of Dwyer is provided here). This room is sealed electrically. Here we were introduced to the construction of a thermostatic oil bath of $28^{o}F \pm 1/1000^{o}F$.

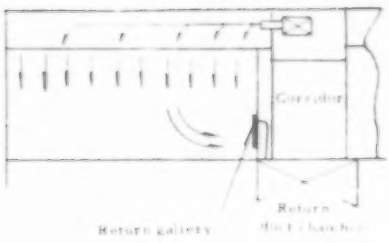


Fig. 4-2

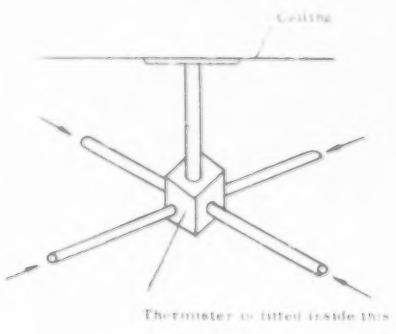


Fig. 4-3

(3)-4-2: Room No. A-5, Electrical Instrument Laboratory

This is the high voltage testing laboratory, and generators capable of producing 150,000V DC and 5,000V AC are located here.

Temperature condition: $73^{o} \pm 1^{o}F$,
Humidity condition: $50\% \pm 5\%$.

(3)-4-3: Environmental Chamber

This room is used for carrying out weather tests in the temperature range $40^{o} \sim 100^{o}F$, and relative humidity range $20\% \sim 80\%$. However, in case of below $30^{o}F$, the temperature is allowed to take its own course.

(3)-4-4. Room No. B-3, Dimension and Optics Laboratory

As shown in Fig. 4-4, this room also utilized the whole of the ceiling as the perforated air inlet, and the circulation is maintained by providing the return grill on the two side walls.

Temperature condition: $68^{o} \pm 1/4^{o}F$ (at FL 45")
Humidity condition: $40 \sim 45\%$
Dust condition: slightly inferior than Class S (Class 100,000 of Federal Standard 209) of the Boeing Co.

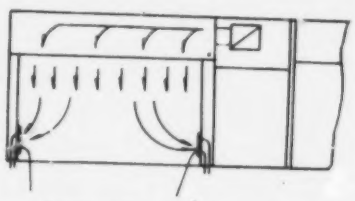


Fig. 4-4

(3)-4-5: Air Conditioner

Various questions regarding the arrangement:

(1) Although the room has been designed to have dust level above the 100,000 class, yet the position of the HEPA filter appeared to be not very sound. This point was also pointed out by the person of the Boeing Co. who was assigned to escort us.

(2) The gallery for the intake of the air from outside was installed only 1 m above the ground level, which also appeared to be not very sound.

Persons Interviewed

Robert A. Hartnett, Robert H. Ledoux Jr.

(Reporter: Tadao Bizen)

4-7 SPACE COMPANY

(1) Location: 1405 East 58th Place, Los Angeles 1, California 90001, Phone: 583-6738.

(2) Date and time of visit: April 17, 1970. 2.00 P.M. to 4.00 P.M.

(3) Brief Sketch of the SPACE Company

The word SPACE is the abbreviation of Scientifically Processed Apparel for Controlled Environments. Although the main emphasis of the company is the scientifically processing of apparels for working in controlled environments, yet it manufactures and markets diverse types of working apparels, gloves and other items.

The processing techniques employed here have been evolved on the basis of painstaking researches extending over years and experience, and the sophisticated type equipment used here produce goods which are suited for even high degree clean rooms. It has also a very efficient consultancy service to solve the problems of the customers concerning elimination of contamination.

The processing technology of the SPACE Co. has solved a large number of problems related to the elimination of contamination from the apparels of the clean room; and the strict specifications of super clean apparels required in electronics, missiles and related fields are enforced very strictly here. The design here aims at satisfying the Class IV as required by the Air Force specification No. T.O. 00-25-203, and in practice the performance is even higher.

Here, all conceivable contaminants like dust, lint, and hydrocarbon etc. (even statical electricity) are removed from

the apparels by treating with especially developed cleaning agents using sophisticated machines. To ensure that super clean apparels reach the customers, specialists guarantee the cleanliness after a thorough inspection with naked eyes as well as with microscopes etc. before shipment to the customers in special packings.

(4) Outline of the visit

(A) Sketch of the visit

We saw here mainly the plant cleaning the apparels for use in the clean rooms. It seems that the demand in this line is not very high at present and hence not very profitable. Production and reconditioning of the conventional type gloves with the help of traditional processes and techniques seem to be the main source of income at present. Considering from the rapidly rising demand for the clean rooms in many industries it seems that the field of scientifically processing of garments for the clean rooms is heading for an extremely promising future.

(B) On the Clean Room

i) Purpose: This is the cleaning plan. where the apparels for the clean rooms are cleaned, dried, inspected and packed. Considered from the nature of the work carried out here, it can be nothing other than a clean room.

ii) Designing, Erection, Supervision: These were carried out by the Micro-Netics Co., Pasadena, California.

iii) Design Specifications:

iii-a) Type: This is a non-laminar flow type clean room, an anemo at the push opening and a register at the pull opening. The filter is located inside the filter casing of the air conditioner.

iii-b) Degree of Cleanliness of the Air: It is a class 100,000 clean room (US Federal Specifications). However, when the cleanliness is determined at the time of actual opera-

tion, it has been found to be of the order of class 10,000. The contamination measurements are carried out twice a day with the help of a dust counter of Royco Co.

iii-c) Number of Circulation: We were told that air is circulated at the rate of 10 times per hour. The capacity of the room is not known, although the floor space is about 700 ft^2 (65 m^2).

iii-d) Temperature and Humidity: The temperature inside the room is 70 ± 1°F D.B. (21.1 ± 0.56°C D.B.), and the humidity is 45 ± 5% R.H.

iii-e) Illumination: It is 100 F.C. (1,110 lx). Fluorescent tubes built inside the ceiling have been used here.

iii-f) Persons Working in the Clean Room: 7 persons, 0.01 person/ft^2 (0.1 person/m^2).

iii-g) High Performance Filter: In the begining Absolute Filter of Cambridge Co. was used, but at present HEPA filter of HEPA Co. located at Pasadena is used.

iii-h) Static Pressure inside the Room: It is + 0.05 inch (+ 1.25 mmAq).

iii-i) Cleaning Device inside the Room: Cleaning is carried out with the help of central vacuum system. The machine used is a small sized Central Vacum CU-7, 640W.

iii-j) Air Shower Room: The persons working in the clean room first clean the bottom of their shoes in the front room provided with air lock, and then enter the air shower room where the dust adhering to the dress is removed by high velocity clean air blowing out of the nozzle. Then only they enter the clean room. A mat is also laid at the entrace of the front room for cleaning the shoe bottom.

iii-k) Air Cleaning Room: The washed and dried apparels are carried to the packing room by hangers mounted on a conveyer belt system. and on the way the dresses are cleaned

in the air cleaning room where clean air is directeu on the dresses.

iii-l) Pass Box: The product given the final touch and packed in the packing room next goes to the pass box from the clean room, and from there the shipping door is opened and the product is shipped out to the customer.

iii-m) Construction of the Room: The clean room is located at one corner of a large laundry plant. It is a woodcn structure using plywood in the walls and the ceiling, and finished with epoxy paint. The floor is of concrete and is given a linoleum finish. The color of the room is yellowish green, and the impression we got is something like that of a glass partitioned room.

iv) Laundrying Equipment

iv-a) Principal equipment: Washing machine: One 3ϕ x 220V x 12A x 60c/s machine of Hydroxtor Co. Dryer: One 3ϕ x 220V x 8.1A x 60c/s machine of Cissel Dryer Co.

iv-b) Method of Laundrying: The laundrying and drying are carried out at about 165°F (73.9°C), and disinfection is carried out at about 256°F (124.5°C). The heat source is a

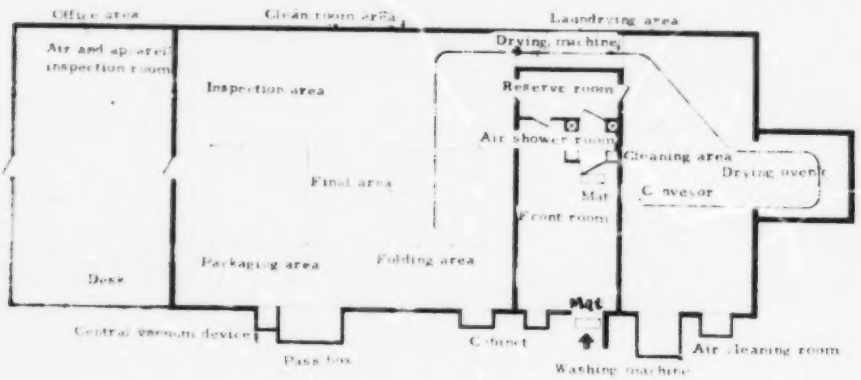


Fig. 1. Floor plan of the laundry for clean room apparels (No scale).

steam boiler fired by natural gas. The steam produced is 110 PSIG (7.7kg/cm^{2}G), which is used after reducing the pressure depending upon the objective. The pipe layout of the boiler has been designed carefully so that it remains wholely outside the clean room.

iv-c) Inspection of the Dust Content of the Products: This inspection is carried out according to the specifications of the US Air Force. Normally two out of every hundred items are sampled out at random for inspection. As 500 apparels are washed here per hour, 10 apparels are subjected to inspection for dust content per hour. The apparel inspected is placed on a suction desk of the size 1ft x 1ft (300mm x 300mm), and vacuum pump sucks in air at the rate of 14l/min from one spot. Suction pumps of the following make are used here.

a) Braun-Knecht-Heiman Co., b) Braun Chemical Co., c) Scientific Supplies Co., and d) Div. of Van Waters & Rogers Inc.

The capacity of the pumps used here is not known, although the maximum capacity appeared to be about 500 mmHg.

(C) Reference Items

1) Points where caution should be excercised during laundrying:

a) All the defects and wear and tear of the apparels should be checked with extreme care and mending should be done whereever necessary.

b) All the chucks should be kept closed.

c) The mechanical operations should be reduced to absolute minimum.

d) Weakly alkaline or neutral soap or detergent should be used.

e) As far as possible the bleaching agents should not be used. If the use becomes unavoidable, then a bleaching agent as dilute as possible should be used.

f) As far as possible, the laundrying temperature should be kept below 140°F (60°C).

g) Squeezing and stirring should be reduced to minimum. The hanger and rope made of plastics should be replaced periodically.

h) Ironing should be resorted to only as the ultimate step. In case the use of iron becomes unavoidable, overheating the iron should be avoided. Ironing should be carried out at as low a temperature as possible.

2) US Air Force Specification No. T. O. 00-25-203

a) The laundrying of apparels to be used in the clean rooms should be carried out in rooms where contamination is strictly controlled and using special type equipment exclusively developed for the purpose. Both dry cleaning and cleaning using water are approved. Liquid synthetic detergent is recommended when water is used for washing. If mineral free water is not available, the softening agent should be added to the water and the water temperature should remain within the range of 140°F(60°C) to 150°F), (65.6°C), (and in no case it should exceed 160°C(71.1°C), for apparels of white color, and within the range 120°F(48.9°C) to 130°F (54.4°C) (and in no case should exceed 140°F, i.e., 60°C) for the colored apparels. White and colored apparels should never be washed together. Chemicals for reducing the statical electricity should be added during the final rinsing, after which the apparels are allowed to drip dry. The water used for washing should be properly filtered before hand.

b) The appliance for dry cleaning should be carefully designed to carry out filtering and evaporation of the solvent continuously. The filtering system is determined by the designer very carefully so that it passes the limited linting test when the apparels are being treated by the machine. This shows that filtration should be of a very high order, capable of eliminating particles of size 0.5μ or above. Improper filtration of the dry cleaning solvent, partial seepage of the solvent, and improper removal of the special type medium used for removing the dirt etc. result in the apparels' turning yellowish, or getting de-

colored, or loss of lustre. Extreme care should be excercised to ensure that such results are not produced at the end.

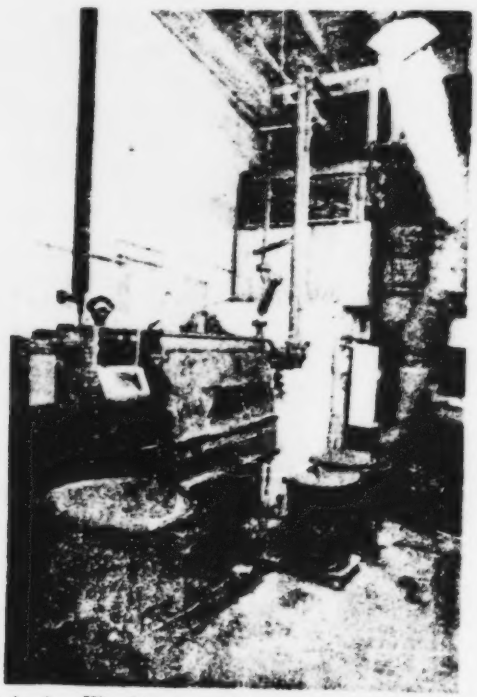


Photo 1. Washing machine and drying machine.

c) Laundrying of the apparels to be used inside the clean rooms is carried out on contract basis at present. However, in case economy is ensured, the laundrying facilities should be set up within the establishments where clean rooms are n constant use on a large scale.

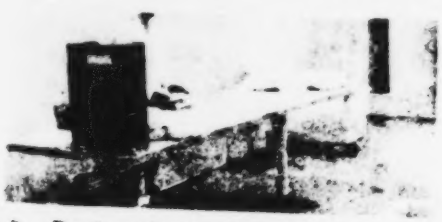


Photo 2. Dust content inspection of the apparels.

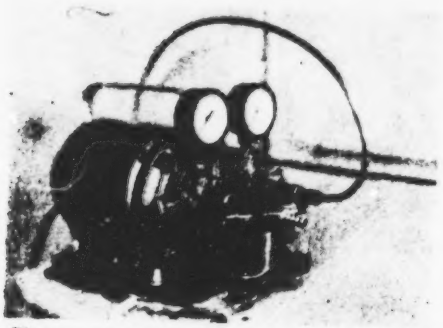


Photo 3. Vacuum pump used for dust content inspection.

Photo 4. Folding and packing of the apparels after cleaning.

d) The laundrying service involves the duty of collection of dirty apparels and the delivery of the clean ones after washing. The apparels which become too old and unusable should be removed from the inventory and replaced by new ones. Inspection of the dresses for wear and tear and their repair also forms a part of the duty of the launderers. However, whether these should be discharged or not should also be evaluated carefully. Special care should be taken about the torn strings and stuck up zips. After washing and final inspection, the apparels should be folded and then sealed inside plastic bags. These plastics bags should be made in strictly controlled environment. The launderers who can render the above services and who can satisfy the stringent requirements of limited linting agreed upon by contract are alone enlisted as the approved parties to handle the job.

3) The ASTMF 51-65T 'Method for determining the size and number of contaminant particles adhering to the apparels for clean rooms - A draft' has been given below in the Appendix.

(5) Persons Interviewed

Howard Scott - General Manager.

The author wants to express his gratitude to Mr. Scott for the valuable assistance he has rendered during the AACC exhibition.

APPENDIX

METHOD FOR DETERMINING THE SIZE AND NUMBER OF CONTAMINANT PARTICLES ADHERING TO THE APPARELS FOR CLEAN ROOMS - A DRAFT[1]) ASTM F51-65T (PROMULGATED IN 1965[2])

This draft was approved by the sub-committee set up for drawing up the standard specifications, and was put into actual operation even before it was finally adopted. However, later on the draft was adopted as a standard after following the established procedure. Any proposal for modification of this standard should be sent to the office of the association located at No. 1916, Reiss Street, Philadelphia, Pennsylvania, 19103.

1. Scope: This draft gives the procedure for measuring the separable contaminant particles of size above 5μ adhering to the fabric of the apparels used in the clean rooms.

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2. Outline of the Method

2.1 Filtered air is sucked in for one minute at each place at the rate of 14ℓ /min from 5 specified spots, each of size 0.01 ft^2, from each apparel. The air thus sucked in from the dress is next allowed to pass through the disk of the membrane filter so that the particles thus sucked in strike against the filter surface. Next, the filter disk is studied under microscope for counting the number of particles of size above 5μ brought by the air from the apparel. The technique for filtration and counting the particles is the same as that established in ASTM F25 which lays down the specifications for determining the size and number of floating contaminant particles in the clean rooms and dust control areas of the electronic and related industries[3]. The method proposed here has been drawn up within the scope of F25 deliberately in order to reduce the necessity of new technique and equipment to absolute minimum.

3. Definition of the Terms Used Here

3.1 Vide the terms used in F25.

3.2 Fibre here means the particles of length above 100μ and whose ratio of length to breadth is more than 10:1.

4. Equipment

4.1 Filter assembly and adaptor[4]: Vide Fig. 1.

Fig. 1. Filter assembly and adaptor

4.2 Vacuum pump and suction device: These should be capable of producing a vacuum of the extent of 500 Torr (500 mmHg).

4.3 Flow meter and orifice: These should have the capacity of 10ℓ/min.

4.4 Membrane filter[5]: This consists of an assembly of two filters, one black and the other white. The black one has a diameter of 47mm provided with printed lattice design with 3.08mm interval, and the pore diameter is 0.80μ (for fibre particles). The white one has also a diameter of 47mm, with 5.0μ as the pore diameter (air prefilter).

4.5 Microscope and the counting device: The devices laid down for F25 are adopted here. (These devices have been shown in Fig. 2).

Fig. 2. Microscope and microscope lamp for determining the number and size of the particles.

5. Conditions that Should be Set Up for Carrying Out the Test

5.1 In sampling here, the particles originating from the surface of the apparel are collected after they strike against the membrane filter while being carried by the air blast which has passed through a 5μ prefilter on the way. The surface of the lattice filter mounted on an open-type aerosol filter holder is placed on the exterior side surface of the apparel to be inspected, and the

apparel is firmly clamped to the filter holder with the help of an adaptor provided on the adaptor of the air filter. While the test is in progress, the apparels should either be kept hanging, or should be arranged carefully in order to reduce to possibility of unrelated contamination to the minimum.

5.2 The five standard sampling locations have been shown in Fig. 3, and 14ℓ of air is sucked in from the fabric at each of these five locations in a minute. The area equivalent to that covered at each of these spots during sampling is enough for sampling the contaminants on the cap, helmet, towel, and boots with plastic bottom etc. However, in case of boots made from fibre, sampling should be extended to two spots.

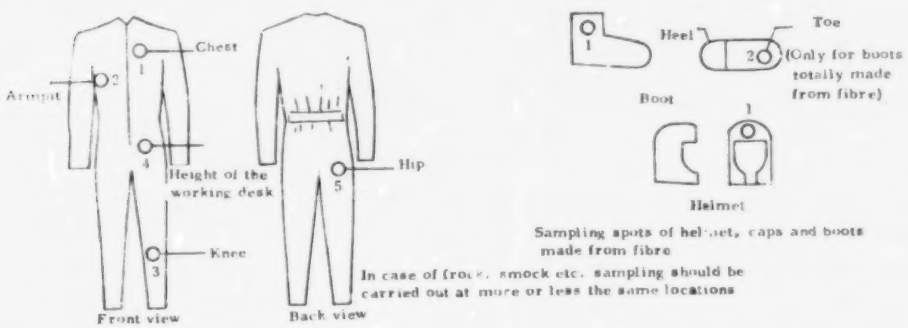

Fig. 3. Contaminant sampling spots for the apparels used in the clean room.

5.3 The positions given above are the approximate positions, and can be varied slightly. Necessary modifications can be made with the equipment so that specially designed filters can be used during sampling.

6. Preparing the Equipment for Sampling

6.1 The procedure has been laid down in Section 6 of F25.

7. Sampling Procedure

7.1 With the pipe layout suiting the pressure needs for sampling, the filter holder is connected to the vacuum device. This

vacuum device should have the capacity to produce an air draft of 14ℓ/min at the vacuum state required for the sampling, (viz., 350 Torr, 350mmHg). An open-type holder can be used. However, a holder provided with a flow controlling orifice or one connected with the flow meter can also be used. In case the flow meter is located in between the filter holder and the vacuum device, the correction for standard temperature and pressure should be carried out for determining the actual standard temperature and pressure of the flow.

7.2 The membrane filter is taken out from the container very carefully with the help of a clean pin set and placed on support screen of the filter holder with the lattice printed side facing upwards. Next the adaptor with narrow tip is fitted on it and then the filter is fixed by rotating the fixing ring. As shown in Fig. 1, the O-ring is removed from the tip of the adaptor, and there the 5.0μ air filter is fitted. Next the white filter of diameter 47mm is placed on the support screen and the O-ring is fitted back on it as before. (This filter can be used for a number of samplings).

7.3 After the sampling preparations are completed, the outer face of the apparel is placed on an adaptor with narrow end (male). Next the adaptor-with-narrow-end of the air filter (female) is placed on the sampling area and firmly fitted there.

7.4 The vacuum device is now operated and predetermined degree of vacuum is created which allows the suction of air at the sampling spot at the rate of 14ℓ/min. The sampling spots have been shown in Fig.3, and the procedure laid down in 7.3 above is repeated at each of these spots.

7.5 The filter is next removed with the help of pin set and sandwitched in between clean microscopic slides or placed on Petri dish and carried to the microscope for counting.

8. Procedure for Analysis with the help of Microscope

8.1 Calibration of micrometer scale of the eyepiece: The eyepieces for measuring different magnifications are determined with the help of a stage micrometer. The main graduation (100 inch scale) is made equivalent to about 5μ with the help of eye-

piece of 10 times magnification and objective of 10 times magnification.

8.2 The filter is taken from the petri dish and placed on 2 x 3 in microscope slide with the filter surface facing upwards. It is recommended to use a little silicone stop cock lubricant to make the slide move lightly prior to transferring the filter on it. This facilitates the holding of the filter at a flat level.

8.3 The illumination lamp is adjusted so that about 45° light incidence is maintained as this gives maximum illumination of the particles.

8.4 Each and every lattice enclosed area is investigated thoroughly using mechanical stage. The number of particles is determined employing gaiting technique, and the particles divided into two categories.

8.4.1 Particles with maximum diameter 5μ or above[6].

8.4.2 Fibre (vide 3.2 above)

8.5 The number of particles in a large number of lattice compartments selected at random is counted, and this is continued till the following statistical condition is fully satisfied.

$$F_N \times N_T > 500$$

where, F_N: Number of lattice compartments where counting has been carried out.

N_T: Total number of particles counted in the area covered by F_N.

9. Results of Counting

9.1 In calculating the total number of particles above the size 5μ and the fibres on the filter, the values obtained above for each category are multiplied by $100/F_N$. Here, F_N is the number of lattice compartments where counting of the particles has been carried out as mentioned above. (The effective area of the filter is divided into 100 lattice compartments). In calculating the number of fibre particles per square foot[7], just multiplying the

total number of fibre particles on the whole filter surface by 20 will be enough. However, in this case a condition is attached, viz., that sampling has been carried out at 5 spots on the apparel.

9.2 In the final report, the total number of particles per square foot for the two categories should be shown separately.

9.2.1 Particles of the 5μ or above.

9.2.2 Fibres.

These two figures will show the number of particles and fibres per square foot collected from the most representative sections of the apparels.

10 Factors Affecting the Accuracy and Precision

10.1 The accuracy and precision of this method are not higher than those normally obtained with the total of the variables. It is necessary to have a highly skilled person to handle the microscope to reduce the personality factor involving the variables to the minimum. A trained person is quite aware of this variable factor, and thus he can reduce the error to the minimum.

10.2 The figure 500 has been adopted above as it was found to be advantageous.

10.3 For training the personnel, it is better to sandwitch the lattice filters in between microscopic slides and preserve them as the standard specimen after determining the intermediate intensive examples. However, standard specimens for training can also be purchased.

Addenda

A.1. Method of special sampling of the clean room apparels for within the factory selection.

A1.1. 1 ft^2 stainless steel frame is used as the sampling jig. The sides of the frame are 3 inches wide so that they can stand on their sides. One face of the frame is provided with a screen for supporting the surface of the apparel to be inspected.

A1.2. The frame is covered entirely with the apparel. By this the zone of the apparel to be sampled can be stretched flat on the screen. The sampling surface is fixed firmly on the frame with the help of one or two tightening clamps.

A1.3. The sampling device contains a black membrane filter with 47mm diameter and 0.8μ pore diameter. The air flow is adjusted to 20ℓ/min with the help of a flow meter, and if 8 overlapping pass test is carried out, then the whole sampling surface can be covered within one minute. The opening of the sampler should be very close to the sampling surface.

A1.4. The membrane filter is removed, and the particles and the fibres are counted according to the procedure laid down in Items 8 and 9 above.

A.2. Proposed classification of the apparels to be cleaned.

Note: The seams of the apparels, towels, caps, hoods, boots and other items which show clear signs of generation of torn fibre or lint should be washed again or abandoned. The clean room apparels brought for cleaning should be free from unpleasant odor.

Class	Contamination level per square foot of the fabric	
A	Maximum below 1,000	10 fibres above the length of 5μ
B	Maximum below 5,000	25 fibres above the length of 5μ
C	Maximum below 10,000	50 fibres above the length of 5μ
D	Maximum below 15,000	125 fibres above the length of 5μ
E	Maximum below 25,000	175 fibres above the length of 5μ

Footnotes

1) Pending its adoption, it is under the jurisdiction of F-1 Sub-Committee of the ASTM which deals with the materials used in the electronic and micro-electronic equipment.

2) It has been accepted by the Administrative Committee on Standardization on July 22, 1965.

3) It has been given in the book.

4) Particle monitoring device for fabrics XX 50 047 40 of Millipore Filter Co. Bedford, Masachusettes, or equivalent product. Adaptor No. XX 50 047 45 for F25 equipment or similar product.

5) Millipore Filter Co. produces filters satisfying all the conditions required here.

6) Particles below the 5μ size cannot be counted by this process.

7) The sampling areas of the various items of the clean room apparels have been designed to suit the assembly and the adaptor (vide Fig. 2), and each sampling spot has an area of $1/100 ft^2$. When 5 spots are sampled, in all 1/20 sqft of the apparel is sampled. Also vide addenda A1 for within the factory selection method for special sampling of the apparels.

(Reporter: Yamagishi)

4-8 AACC (AMERICAN ASSOCIATION FOR CONTAMINATION CONTROL)

1. Location: Six Beacon Street, Boston, Mass., 02108, U. S. A.

2. Date and time of visit: April 20, 1970, 9. 00 A. M.

3. Brief Sketch of the AACC

3-1. Foreword

The AACC has been established with the sole object of developing technology for controlling contamination in a closed system of gas or liquid. Because of this basic outlook it has succeeded in making rapid strides eversince its incorporation in 1961. The present membership exceeds 1, 500 persons, representing the industry, science, medicine and government.

Eversince its inception, the Executive Board and the Technical Committee have been trying their best in achieving the following objectives laid down in the Articles of Association.

a) Developing Technology for controlling contamination in the closed system of gas and liquid and promoting studies on technologies associated with contamination control.

b) Promoting exchange of information among the technologists.

c) Encouraging research and education in the field of contamination control in order to raise the level of knowledge, technology and capability in all.

d) Promoting education of the people showing keen interest in controlling contamination.

e) Convening periodical meetings for publishing articles, holding discussions and drawing up plans for research related to contamination control.

f) Conferring degrees and publishing acknowledgements for encouraging people to carry out researches in contamination control technology.

g) Publishing mouthpiece of the Association, periodicals, articles and reports for communicating useful information to the scientists and technologists working in various fields related to contamination control.

h) Establishing close cooperation with the government, industries, learned societies and research centers, and promoting the drawing up of standards and codes related to the control of contamination.

i) Assisting the members of the AACC working in the field of contamination control in establishing mutual contact.

3-2. Basic Policy

The members of the AACC will try their best in developing the science and technology for controlling contamination in order to promote the health and welfare of the people in general, and for the benefit of the government and the industries. The members of the AACC, hence, resolve as follows in order to achieve the objectives mentioned above.

a) All the activities, both private and public, of the members of the AACC will be motivated by the basic outlook that the interests of the AACC are in complete agreement with those of the government.

b) All the activities will be motivated by truth, precision, fair distribution and good interest as accepted by all.

c) Support all the activities associated with the development of science and technology for controlling contamination.

d) All the activities will aim at promoting the basic objectives and implementing the programs of the AACC, and besides the activities of the branches will be assisted through active participation of the AACC members.

3-3. Set-up and Working

The Board of Directors will constitute the executive body of the AACC.

The Board of Directors will consist of 27 members elected from among the members of the AACC.

The Board of Directors will be headed by a Chairman, who will have two Vice-Chairmen under him. Again, the whole of the USA will be divided into six districts, and there will a Vice-Chairman in each of these six regions.

The routine day to day activities of the Board of Directors will be carried out by the Secretary.

A branch will be established in each of the above six districts, and each branch will elect the office bearers and hold annual conference with the direct assistance and cooperation of the headquarters.

3-4. Members

The membership of the Association will be open to persons having interest in controlling contamination in closed systems of gas and liquid.

The present membership is about 1, 500 persons representing diverse fields like quality control, plant engineering, hospital management, bacteriology and medicine etc. Again, the large enterprises and the government are actively participating in and making generous contributions to the AACC programs for promoting the contamination control technology.

3-5. Privileges of the Members

a) Annual subscription to Contamination Control.

b) Annual subscription to the News Letter of the AACC.

c) Annual subscription to the mouthpiece of the AACC.

d) Receiving the latest reports and catalogues.

e) Others.

3-6. Duties of the Members

a) Participating in the conferences convened by the branches so that the members can contribute their share in the development of contamination control technology.

b) Cooperating with the members of the various sub-committees for preparing the technical reports.

c) Participating in the annual technical conferences for knowing the latest information and trends.

d) Others.

3-7. Technical Sub-Committees and Steering Sub-Committees

The formation of the technical sub-committees constitutes the backbone of the AACC. The various technical sub-committees bear the responsibility of editing the latest technical reports contributed by the members.

Besides the technical sub-committees, the steering sub-committees also contribute to the efficient working of the AACC.

Steering Sub-Committees

Annual Technical Conference Sub-Committee

Membership Sub-Committee

Technical Sub-Committees

Bacteria Sub-Committee

Standardization Sub-Committee

Design, Erection and Operation Sub-Committee

Handbook Sub-Committee	Hospital Sub-Committee
Educational Sub-Committee	Pharmaceuticals Sub-Committee
Publication Sub-Committee	Apparels and Laundrying Sub-Committee
Awards Sub-Committee	Cleaning and Packing of Parts Sub-Committee
Research Sub-Committee	Measurements Sub-Committee
	Micro-Electronics Sub-Committee

3.8 Technical Conference

The AACC convenes technical conference every year. More than 50 world renowned experts on contamination control read their papers in this conference, followed by a round-table discussion. In all more than 8,000 persons have participated in the technical conferences held since 1961, when the first conference was held. This conference also holds an exhibition simultaneously, where the latest instruments and equipment are exhibited. Furthermore, the regional branches also hold technical conferences of two-day duration, besides holding monthly technical meetings. These conferences and meetings are very useful to the members as they provide the forum for exchanging views and information on the latest developments in the technology of contamination control.

4. Annual Conference and the Exhibition of the AACC for the year 1970

4-i. Brief Introduction of the Papers Submitted to the 9th Annual Conference of the AACC

A. On Problems related to Planetary Quarantine

A-1. Experimental Investigation of the Phenomena Associated with Planetary Quarantine, by D. L. Enlow.

The object of this study was to determine the most important physiological recontamination form as a part of the 1973 Viking Project. To this end, studies were carried out on the physiological phenomena influencing the form of recontamination associated with planetary quarantine, and a new plan for experiment was tried. As it is already known that the power of adhesion and the electrostatic characteristics of the microbes constitute very important parameters, these characteristics were studied in the environments of normal atmosphere and of vacuum. The microbes were placed in a surface whose electrical potential could be varied arbitrarily and their electrostatic characteristics at different potentials were determined quantitatively. Researches of this type are very important for providing useful data for the future Mars landing vehicles whose primary duty will be to detect life on the planet.

A-2. Contamination Control-Apollo Lunar Sample Return Container and Supporting Hardware, by R. H. Liddle.

The containers and the supporting hardwares were carefully manufactured and inspected so that the possibility of contamination of the lunar substances during collection and transportation to earth was reduced to zero. All these containers and hardwares were cleaned thoroughly in a class 100 clean room using extremely pure solvents and ultrasonic cleaning device. The level of cleanliness achieved on the surface was below 10 nanograms/cm^2. This level was confirmed from the data of gas chromatography using the technique for non-volatile residue.

B. Preventing Biological Contamination

B-1. Anti-Bacterial Plastics. by H. B. Hopfenberg.

Dubin and White have secured the US patent on an entirely new and unique type of plastics. It is a polymer containing hexachlorophane and related bis-chlorophenol compound, and during its anticipated life time as plastics its surface is known to

possess anti-bacterial properties. Mixing hexachlorophane in appropriate proportions to various thermo-plastic substances produces materials capable of killing both the gram positive and gram negative bacteria. Researches are in progress at present to study the prospect of applying this conception to the other polymer systems as well. Extermination of the microbes crowding on the surface of the pharmaceutical products will reduce the problem of mutual contamination within the hospital, which is a great headache at present.

B-2. Identification of a Recurring Bacterial Contaminant in a Spacecraft Water System, by A. J. Bryce.

A bio-satellite was launched successfully in June 1969. The passenger was a male Macaque nemestrina on which experiments were to be conducted. One of the requirements of the drinking water system in the spacecraft was maximum 200 colonies of bacteria per ml of water. Biological tests were carried out once before and once after the test of each system. It was confirmed that microbe contamination occurred at random intervals. The Contaminant microbe was identified by carrying out analysis in the laboratory. From the experiment it became clear that this microbe was capable of surviving even in highly sterilized deionized water without any difficulty.

C. Role of Management in Contamination Prevention

C-1. The Role of the Engineer-Scientist in Contamination Management, by K. P. Kozoriz.

The idea of contamination management is usually associated with the end-of-the-line step. Most of the work falls in the category of routine monitoring duty for confirming that the required degree of purity specified for the products is maintained. Monitoring contamination basically involves the responsibility of guaranteeing the quality. The term contamination management immediately suggests some sort of planning. Managing contamination is, in a sense, an extension of the idea of checking contamination. This paper deals with the principles of contamination management. The role the scientist-engineer plays in this conception of 'from begining to end' has been discussed in detail and theorized here in this paper.

C-2. Laminar Flow Clean Room Management, by E. C. Doyle.

This paper deals with diverse aspects of the clean room, for example, the developments that took place related to its structure, developing a system for finding out the conditions of contamination control when the clean room works for 24 hours a day and for 7 days a week, and proper placement of the people working inside the clean room etc. It also discusses the basic qualification and experience that a new recruit should have so that he can become an expert engineer on contamination control in the future. It introduces a very complicated type of clean room containing many novel devices for controlling the required degree of cleanliness.

C-3. People - The Key to Contamination Control, by Harvey Hearing

When the requirement of perfect cleanliness becomes indispensible in a place, the final achievement there is determined by the proper management of the personnel working there. These are the selection of the proper persons, imbue them with the inspiration of achieving their goal, and proper training.

This paper emphasizes the importance of the personnel working inside the clean room, as they constitute the ultimate decisive factor in the success of the project.

It gives the guideline on selection of the most suitable persons who will conform to the stringent requirements of the clean room, and on indoctrinating them thoroughly so that they realize and psychologically accept all the points of caution for guranteeing perfection in their work.

D. Monitoring Technique

D-1 Detection of Ionizable Surface Contaminants by a Conductivity Measurement, by T. F. Egan.

Soluble and ionizable surface contaminants of micro-gram order like the salts used in electroplating, salts falling from the

finger tips and precipitating contaminants from the atmosphere etc. can be detected by measuring the conductivity of water used for cleaning the surface contaminants. The equipment required are very simple and very cheap in price.

All the necessary and related information have been provided so that the engineer successfully implements the test without any lapse. Again, various types of equipment which can be used for measuring the specific conductivity of the solutions as well as the factors affecting the conductivity have been introduced here. The relation between the weight and particle size has also been discussed. The routine use of the above equipment in the manufacturing establishments has also been introduced.

D-2. Response of an Optical Counter to Monodisperse Aerosol, by D. Rimberg.

The response of the counter to aerosol consisting of monodisperse polysterene latex particles has been measured here. A large number of experiments have been carried out on the classification of aerosol according to the size of the particles, and also on evaluating the capacity of the counters in determining accurately the number of particles per cubic volume of air. Again, tests have also been carried out to ascertain whether the performance of the counter is linear with respect to the variation in the particle concentration.

The optical counter was also used for determining the percentage of the aerosol particles passing through the gravity precipitator, which can be used for estimating the size of the particles.

D-3. Calibration Procedure for Automatic Particle Counters, by A. Liberman.

The object of this procedure is to ascertain the response of the automatic particle counters to both the particle size and the particle concentration. The effects of shape of the irregular particles, direction of their distribution and their coincidence have been determined here and special steps have been taken to

eliminate these effects. The procedure proposed here is very effective for the counters in analyzing the floating particles inside gas or liquid.

D-4. Custom System for Measuring Optical Effects of Aerospace Materials Contaminant Deposits, by W. W. Moore.

A special geometrical approach to the method of determining the effects of the surface contaminants on such optical characteristics like frontal surface reflection employing the process of vacuum spectroscopic radiation measurement has been proposed. The research and experimental data have been shown in association with 'Quartz - crystal micro-balance measurement method'. A revolutionary experiment in the field of contamination control and which will be a very useful complement to the existing techniques and methods of contamination measurement has been explained here in a very lucid manner.

E. Cleaning Technique of Artificial Human Organs

E-1. Disinfection of Artificial Kidney Systems. by E. A. Pecker.

The artificial kidney systems, both the centralized systems for catering to a large number of persons in the hospitals as well as the domestic systems used by the individual patients, circulate the dialized solution of salt and glucose maintained at the ideal growth environment, viz., the blood temperature in this case. It is necessary to wash and disinfect these systems either every day or twice in a week for keeping the bacteria population at a low level. The procedure developed for this purpose utilizes formaldehyde or sodium hypochlorite solution, and the results have proved to be very encouraging clinically. Both designing and procedure for disinfection are very important as these are instrumental in guaranteeing the protection of the health of the patient for a prolonged period. A detailed discussion has been carried out here on the present state of the techniques and the devices currently in use.

E-2. The Air Displacement Process in Industrial Ethylene Oxide Sterilization, by R. Ernst.

This report discusses the complicacies involved in sterilization of gas with the help of ethylene oxide. The importance of the water vapor as the carrier while the hylene oxide (of the system) passes through the membrane should not be over emphasized. The molecules of the two interact for restricting the dispersion after the water vapor and ethylene oxide pass through the plastics membrane.

Very conspicuous gas stratification occurs when the evaporation and heating take place improperly, and this hampers the sterilization effect considerably. The dispersion and mixture of the constituents of the disinfectants, air and water vapor become extremely difficult in the static state set-up inside the disinfectant chamber. In view of all these difficulties employing appropriate equipment and properly trained persons is of paramount importance. Over-simplification in certain cases as only created confusion, unreliability, and what is more dangerous from the point of sterilization technology, improper sterilization.

E-3. The Use of a Laminar Flow Room for Protective Isolation of a Bone Marrow Transplant Patient, by C.O. Solberg.

A laminar air flow (LAF) room was used for protective isolation of an year old child undergone bone marrow transplantation for lymphopenic hypogammaglobulineia. The samples obtained from the nose, throat, arm pit, inguinal region, perineum, stool and urine just before the patient entered the LAF room and at 4 day intervals following his admission into the room were tested. From the results obtained, a comparison was carried out on bacterial contamination in the LAF room, in three ordinary isolation chambers and in three ordinary rooms in the hospital.

F. Microorganisms and Inanimate Particles

F-1. Influence of a Bipolar-Oriented Electric Field on Populations of Air-Borne Microorganisms, by A.K. Stersky and T.I. Hedrick.

A study was carried out on the reduction of population of the air-borne microorganisms due to the existence of a bipolar-

oriented electric field using an aerosol chamber whose temperature and humidity were controlled. On the other hand, similar tests were carried out using aerosol chamber possessing bipolar-oriented electric field, but where the aerosol was generated at both the poles continuously. The two sets of data obtained were compared.

The effects of the bipolar-oriented electric field on the multiplication of the air-borne microorganisms were studied by observing the killing of the living cells by radioactivity.

F-2. Mechanism of Small Particle Re-Entrainment from Flat Surfaces, by J.S. Punjrath and D.R. Neldman.

The possibility of the flat surface acting as the source of air-borne contamination was studied by exposing a flat surface with an accumulation of particles of known size to an air flow of known characteristics inside a low speed air-flow chamber. A hypothesis was proposed here on the mechanism of re-entrainment of the particles and the validity was tested. The mechanism was found to possess two components, (a) the particles start moving when the shearing stress on them exceeds the frictional force acting on them, and (b) the particle, which starts moving by the transmission of the momentum from the particle moving from the very beginning, slowly drifts to the down stream.

The above were confirmed from the theoretical equation as well as from a comparison of the experimental data.

It was found that if the flat surface is sufficiently large, then it can become a potential source of contamination due to the air flow ordinarily existing inside a closed space.

G. Prevention of Contamination in the Atomic Power Industry

G-1 Design of Adsorber Using Activated Carbon, By J. Douis Kovach.

General consideration proves to be advantageous in determining the conditions for designing activated carbon adsorber for

a particular system. Here cascade method has been proposed for supplying the data on reference device.

It is possible to clean a large number of liquids with the help of active carbon. Although unit operation like adsorption is in vogue for the last two decades and half, yet it is a comparatively virgin field. This is because, the designs till now have been drawn up on the basis of the experimental data, and almost no theoretical study has been carried out on the topic. The object of this study was to evolve a technique for designing at least practical adsorbers, if not the most appropriate ones.

G-2. Detection of Composition Differences at Surfaces by Adsorption/Desorption of Radiotracers, by Dale A. Brandreth and Rulon E. Johnson.

A new method has been developed here for detecting contamination on the solid surface. It is the process of detecting the partially released radiotracers after adsorption with the help of autoradiography. This method has been developed for detecting the organic and inorganic contaminants on the surface of glass, quartz and metals etc.

H. Sterilization Technology

H-1. Ultrasonic Sterilization, by Edwin A. Pecker.

It has been known for a long time that the ultrasonic energy is capable of changing the live-structure in the living beings. The devices for ultrasonic sterilization have been developed taking advantage of this. All the microorganisms including the spore forming bacteria can be exterminated in a low temperature aqueous solution with a skillful combination of 400KC ultrasonic energy and the detergent. The principles involved in designing the ultrasonic devices and their performances have been discussed here.

H-2. Sterilization of Electronic Materials, by J. J. Julis.

This study was carried out to explore the possibility of sterilizing the electronic materials in the temperature range

from ordinary temperature to 125°C by adding sterilizing chemical (like resin and polymer producing formaldehyde) to the potting compound during the curing operation. It has been claimed here that the internal sterilization of the potting compound is possible by applying the technique of cell burying.

H-3. The Microbiology of Hospital Cloth Surgical Packs Prior to Sterilization, by R. S. Lloyd.

Preparing and sterilizing surgical cloth are two of the indispensible routine duties in all the hospitals. Quite often it has been conclusively proved that infection within the hospitals and mosocomial infection have occurred from the contaminated surgical gauge and other surgical instruments as well, and not only from the contaminated lint adhering to the wound or the dust. Recently, experiments have been carried out at two hospitals for obtaining the data on the level of contamination prior to sterilization of hospital cloth from which surgical packs are made. A large number of surgical packs prepared from hospital cloth after washing and just ready for sterilization were studied from the angle of bacteriology, and the bacteria population per square foot was determined.

H-4. Aseptic Maintenance by Pressurization, by C. Cheater, R. Homsey, J. Sontowski and M. Long.

As a part of the NASA Langley Project, the General Electric Co. has carried out a series of tests for ascertaining the possibility of maintaining the aseptic state by pressure. It was found that the technique used was extremely sensitive in detecting the infiltration of the microorganisms through the pores of the membranes. According to the data obtained, infiltration by even a single microorganism can be detected by this technique.

The experiment consisted of two stages. In the first stage, the pores of the membrane were tested in static state with particles on which the force of gravity alone was acting.

In the second stage, the pores of the membrane were sealed with the culture medium, and its capability to check the infiltration of air-borne microorganism was tested in small-sized air

pocket. The device especially developed for this test has been found to be capable of bouncing the microorganisms on the membrane at an air speed of 40 miles/hr.

I. Preventing Contamination in Pharmaceutical and Food Industries.

I-1. Contamination Control Requirements Indicated by USP. 18., by J. H. Brewer

This paper deals with the environmental control requirements in the food and pharmaceutical industries. It also discussed the manufacturing processes that satisfy the U.S. P. XVIII and other specifications.

I-2. Contamination Control in the Food Industry, by R. M. Darrah.

One of the most important problems in the food processing industry is how to prolong the life of the products. Recently, more and more attention is also being paid to the question of preventing cotamination . Designing of new plants has come under the great strain with the range of above 95% specified in the NBS method and the use of laminar flow system using HEPA filter, and this has posed a new challange to the contamination control industry.

J. Case Study of Contamination Prevention.

J-1. Travelling Clean to the Moon, By J. P. Ostaski.

The author discusses here the contamination control activities carried out by the North American Rockwell Corporation for maintaining the required degree of cleanliness in the command module and the service module at the Kennedy Space Center. The contamination control techniques employed for satisfying the specification drawn up jointly by the North American Rockwell Corporation and the NASA for controlling the environment both inside and outside the spacecraft, the equipment and materials

used inside the spacecraft, the apparels and the personnel etc. have been discussed here. The zones where the prevention and control of contamination are applied are the Manned Spacecraft Operations and Checkout Building (O & C Building) = (Assembly plant), VAB, and Pad A and B of the Launch Complex 39.

Again, the procedure for maintaining cleanliness during repair, exchange and maintenance of the spacecraft system has also been discusssed.

J-2. Mechanical Equipment Evaluation Using a Liquid - Borne Particle Monitor, by C. Falkner.

With the ever-increasing complexity in the manufacturing process and hightening conciousness for contamination control, the requirement for more and more refined methods for evaluating the state of the machinery and equipment used during the manufacturing process is rising steadily. Two mutually differeing requirements have been discussed here in this paper.

1) Monitoring the number of fibrous contaminants and solid particles contained in the liquid during the course of operation.

2) Detecting the damages due to friction caused by the large scale sudden increase of the solid particles produced during the course of the working of the machines.

J-3 Now Clean Semi-Conductors Ultrasonically, by J. E. Smallwood.

K. Contamination in the Present-Day Hospitals

K-1. Toxological Residue Contamination Problems Associated with Sterilization in the Modern Hospitals

The use of EO (ethylene oxide) became very wide spread in the hospitals during the early part of 1960. However, a number of problems arose when the equipment employed for the purpose was used hurriedly without allowing sufficient time for letting the gas to be released from the plastics.

Blood hemolysis was confirmed up to 5 days following the sterilization. It bears some relation with the various parameters of the sterilization cycle and the amount of gas adsorbed and released by the packing material. Compounds like 2-chloroethanol and ethylene glycol are formed due to reaction. The sterilized materials should be exposed to continuously filtered hot air inside a chamber for bringing down the level of the toxicological byproducts of the EO rapidly.

K-2. Gaseous Pollutant Evaluation of a Hospital Clean Room, by J. H. Suffer.

A clinical research center carried out a series of experiments in order to evaluate a dust free hospital room where solid walls were used for controlling the gaseous pollutant and odor effectively. This study was a part of the long term program for improving the method of nursing the post-operation patients (as well as the patients suffering from burns) by setting up controlled environment of known value. The present report discusses the findings of the study carried out on controlling the reactive and non-reactive gases and smell within the system. In the course of the present study, the following procedure was developed. Here, NO_2 gas was used as the tracer and the procedure involves the continuous monitoring of the ventilation rate with respect to the source producing the NO_2 gas continuously. This procedure appears to be far superior to the conventional procedures involving the use of the radioactive and non-radioactive tracers for studying rooms with high ventilation rate.

K-3. Microbial Contamination of Mist Therapy Units in Four Pediatric Wards, by N. J. Patarson.

The discovery of high concentration of Pseudomonas aeruginosa and bacillus coli inside the mist therapy unit in a padiatric ward in a hospital led to the study of this problem in three other hospitals as well. As a part of the study on the scope of contamination, considerable efforts were made to identify the factors contributing to the infection of these microbes to the mist therapy unit, their settling down inside the unit and their elimination from the unit. For tracing the possible route of migration, a study was carried out with the unit in controlled environment in a laboratory.

L. Application of Computers in Controlling Contamination

L-1. The πMC Particle Measurement Computer System, by C. F. Frith

Analysis of the particles constitutes a very important task in any contamination control program. The πMC computer system has been developed for eliminating a large number of mistakes involved in the currently used techniques. This system has created a prospect of automatically monitoring the particles employing the speed of the computer and the resolving power of the microscope. It will be possible to carry on measurements in detail not only with the particles appearing on the whole field of vision, but even with the individual particles. Again, it will also be possible to study the samples for determining the physical characteristics, not to tell of the size.

A comparative analysis has been carried out here between this system and the other currently used automatic measurement techniques, and it has been shown that this system can be applied successfully conforming to the specifications. Finally the merits and the limitations of the system have also been discussed.

L-2. Engineering Usage of Computerized System to Plot and Calculate Air-Borne Particle Count Data as Time Function, by R. M. Seip.

This new system is basically a combination of the modern data analysis system Fortran IV program and a large or small computer. By using this system it is possible to store a large volume of data, calculate various types of parameters, and plot the data in the form of X-R histogram in the chronological order of year for facilitating the interpretation. The application of this system will throw new light on the quantitative variation of the air-borne particles with time, which remained elusive so long because of the limitations imposed by the manual calculation method.

L-3. Statistical Processing of Microbiological Data with the Digital Computer, by D. Drummond and I. J. Pflug.

M. Equipment and Techniques for Biological Studies

M-1. Bioclean Facility at Ames Research Center for Detecting Micro-organisms in Lunar Materials, by Lehwalt.

Highly sophisticated bioclean facilities have been designed and installed at the Ames Research Center of the NASA for cultivating the organisms which may exist in the lunar materials as well as for determining the characteristics of such lunar organisms. These facilities provide 324 types of environments for promoting the growth of the microorganisms living in the lunar materials. Again, at each of these environmental conditions, 3 types of atmospheric conditions, 4 types of temperature conditions, 3 types of humidity conditions, and 9 types of culture medium and light conditions can be set up. Performances of these devices as well as the procedure for their use have been explained here.

M-2. Vacuum Probe Detection of Trace Contaminations of Penicillin in Laminar Flow Hood, by R. Sterkey.

Laminar flow bench is used quite often in the pharmaceutical industry for preventing the microbe infection of the parenteral products and checking mutual contamination from other chemicals. It is possible to isolate traces of penicillin adhering to the inner face of the laminar flow hood or deposited on various types of instruments and equipment inside the room with the help of vacuum probe. Inspection of the contamination is carried out with the help of bioassay with penicillin control and chromatography.

M-3. Electrostatic Deposition Device to Deposit Monolayers of Bacterial Spores on Test Surfaces.

This device has been developed in Sandia Laboratories to deposit the bacteria in monolayer form on the test surface. The main object is to eliminate the formation of bacterial lumps which accord some degree of protection to the bacteria during the process of dry heat sterilization. The present report deals with the design of the device as well as the results obtained by using it in detail.

N. Other Problems

N-1. Clean Packaging Materials and Methods, by D.C. Anderson.

The present state of cleaning and handling of the film products used as the super-clean and non-electrostatic packaging material has been explained here in a very lucid language. The detailed data regarding the films of nylon, polyethylene, and fluorohalocarbon etc. have been given here together with the packing methods best suited for each of these.

N-2. Controlled Environment - Its Place in Your Home, by K.E. Ericson.

This project was undertaken to investigate the effects of perfectly controlled environment - it means correct system of heating and air exchange installed in the house - on the day-to-day living and health of the people. Here, perfect air conditioning system was installed in three types of houses. The system was provided with heating, cooling and humidity controlling devices, and completed with two prefilters and one final HEPA filter. The investigation produced very interesting results.

N-3. Odors and Their Control in Laminar Flow Area, by J.W. Johnson, Jr.

This report deals with various characteristics of odor, like size of the molecules, concentration, density and mechanism of stimulation etc. The technique of removal of the odor, adsorption of the odor on the surface and the effect of such adsorption on the HEPA filter etc. have been discussed.

4-2. Parties Participating in the Exhibition of the 9th Annual Conference of the AACC and the Products Displayed

1) Air Technique Co. (1717 White Head Road, Baltimore, Maryland, 21207).

The products displayed are used for measuring the aerosol. On the spot demonstration is possible with all the units displayed.

2) American Air Filter Co. (215, Central Avenue, Louisville, Kentucky, 40208)

Equipment covering all aspects of clean room system have been exhibited. Besides the equipment related to the clean room system, air handling units, condensers and other equipment have also been displayed.

3) Angelica Union Co. (700, Rosedale Avenue, St. Louis, Missourie, 633112).

The exhibits include apparels of various types, like overalls, hoods, boots, gloves, sundry cloth items used in cleaning etc.... 'People are wrapped up for protecting the products' seems to be the motto here.

4) Aqua Media (1210, Elco Drive, Sunny Vale, California, 94086)

The exhibits include water cleaning equipment, evaporators for water, low ionization device, and cleaning agents etc.

5) S. Brickman Co. (536, Gregory Avenue, Vihoken, New Jersey, 07087).

The exhibit is a newly developed Brickman Biohazard Safety Cabinet. It renders excellent service to both the workers and the work carried out by removing the dust. The newly developed system of air flow obstruction wall maintains the germicidal effect inside the cabinet. Again, the flow in or flow out of the air-borne particles is also checked here.

6) Cambridge Filter Corporation (1255, Sylacauga, New York, 13201).

The exhibit is a Cambridge Absolute Filter provided with all the accessories and the prefilters. Practical demonstration of sliding type housing for laminar flow room and ultra cell framing system has also been given.

7) Climet Instrument Co. (1240, Birchwood Drive, Sunny Vale, California, 94086).

This company has exhibited instruments used in the field of molecular analysis.

8) Commercial Carpet Corporation (8899, Bivery Bowlbardas 906, Los Angeles, California, 90048).

Various types of carpets and carpeting materials have been displayed.

9) Coulter Electronics Industrial Division (801C, American Street, San Carlos, California, 94070).

Coulter Electronics has exhibited molecular monitors for liquids and air. The highlight of the exhibition was the display of Model T Coulter Counter, which is generally believed to be the only perfect device for classifying the molecules according to the size.

10) Custom Plastics Co. (2129, North Sea Man Avenue, South Elmontey, California, 91733).

Dryers, storage boxes, acryl dry box and laminar flow hood etc. have been displayed by this company.

11) Environmental Research Corporation (3725, North Dunlop Street, St. Paul Minnesota, 55112).

Equipment for preparing samples, land grain impactor, high volume air sampler, atomized aerosol generator, and diverse types of measuring devices have been displayed by this company.

12) Far Company (P.O. Box 92187, Airport Station, Los Angeles, California, 90009).

The exhibits include air filter package unit, HEPA filters, and clean room equipment etc.

13) Fashion Seal Uniforms (Superior Surgical Manufacturing Co., 63, New York Avenue, Huntington, New York, 11743).

The apparels to be used in the clean room developed recently have been exhibited.

14) Flanders Filter Co. (P.O. Box 1219, Washington, North Carolina, 27889).

The exhibits here include gaskelless filter, holding frame, terminal filter frame, enveloping walls and ceiling, and devices for eliminating the necessity of using gaskets in the already installed equipment etc.

15) HEPA Corporation (1742, Flora Del Avenue, South Elmontey, California, 91733).

Various types of HEPA filters have been displayed here.

16) Liberty Industrial Co. (598, Deming Road, Berlin, Connecticut, 06037).

The exhibits here include odor hood, metal horizontal flow bench, shoe cleaner for table top laminar flow working station, Ticky mat, and mat to be laid on the floor of the clean room.

17) Micron Clean Uniform Service (R.D.#3 Platekil Turnpike New Bar, New York, 12550).

The exhibits were the various items of apparels used in the clean room.

18) Millipore Corporation (Ashby Road, Bedford, Massachusetes, 01730).

The exhibits include a computer system for automatic measurement of the solution and special type materials required for regulating the air-borne fluid system.

19) My Safety Appliances Co. (210 Bradock Avenue, Pittsburgh, Pennsylvania, 15208).

Sophisticated type filtering materials with filtering efficiency ranging from 35% to 99.999% as well as filters for eliminating contamination in gas were exhibited here.

20) Multibent Products Division (1400 North Costner Avenue, Chicago, Illinois, 60651).

The exhibit here was Multibent unitary.

21) Optic Air System Co. (420 Bernett Avenue, Sylacauga, New York).

Optic super clean air system, clean bench, odor hood, instruction type air bench etc. were among the items displayed by the company.

22) Politmarix Co. (San Carlo, California)

Water cleaning equipment were displayed here.

23) Royco Instruments Co. (141 Jefforson Drive, Menro Park, Califor.ia, 94025).

Equipment for carrying out automatic measurements with the liquids and air were among the items displayed.

24) Scientific Enterprises Co. (P.O. Box. No.220, Bloomfield, Colorado, 80020).

Electrostatic control devices and other items were displayed here.

25) S- -e Division (U S. Industrial Globe Co., 1405E58 Place, Los Angeles, California, 90001).

The exhibits consist of the information and samples related to the manufacture and washing of the clean room apparels and their rental program.

26) Turner Supply Co. (3370 San Fernando Road, San Fransisco, California, 90065).

Shoe bottom cleaners, floor mats for general use, ultra clean wiper, ASTM F25-63T, air sampler, two-way modular, laminar flow unit, air sampling equipment and other devices related to contamination control were exhibited here.

27) Telmuko Products Corporation (1465 North Batavia Street, Orange, California, 92668).

The exhibit was a high performance clean bench for carrying out electronic inspection and for checking assembly.

28) Engineering Products Division (United Desk Company, 1200 South Olive Street, Los Angeles, California, 90015).

The exhibit was Agnew-Higgins Laminar flow equipment.

29) Vidaro Corporation (P.O. Box No. 535, 333 Martinel Drive, Kent, Ohio, 44240).

The exhibits here included clean room apparels, cover all, overall, Snud cap, head cover, boots, shoe cover, wiper for cleaning etc.

30) Fred C. Warren and Associates (P.O. Box No. 75822, Sanford Station, Los Angeles, California, 90005).

Shoe cleaners, mats for cleaning shoes, pass through, talk through display wall using partition for filtering the U-V light etc. were displayed here.

31) Western Research Application Center (South California State Business Administration University, Graduate School, Los Angeles, California).

Literature dealing with the importance and the method of using the large accumulation of data in the data handbook including WESRAC and diagrams and charts etc. were exhibited.

(Reporter: Mikami)

5. SUM UP

Although the technique of clean room has been introduced to Japan quite some time back, yet it will be extremely difficult to make a reply with confidence when one is confronted with the question 'how many clean rooms are there in Japan which will conform to the stringent specification requirements ?'.

Considering from the fact that clean room constitutes one of the branches of the broad field of industrial air conditioning, a thorough study of the corelationship of the things produced under the permissible range and conditions of the clean room, their quality, and the results of the various measurements carried out, as well as of the economic feasibility, a study normally carried out with the thermostatic and humidity controlled room equipment, is of great importance. Especially in planning large scale industrial environment, the question of the construction cost and the probable quality of the products constitute the two major issues concerning the life and death of the enterprise.

The quantitative environmental conditions essential for the clean rooms have been laid down in the US Federal Standard N0209a, and techniques and procedures for cleaning air necessary for setting up the above conditions have been discussed widely in a large number of publications. In USA, the above standard as well as the technique have evolved in response to the special type state demand which is amply evident from the history of the electronic industry catering to the needs of the armed forces, missiles and the NASA space development program. However, the question in Japan is different inasmuch as here the industries primarily cater to the demands of civilian nature, and hence these specifications and techniques are to be introduced in a somewhat different context. The Federal Standard gives three basic classifications of the clean rooms, Class 100, Class 10,000 and Class 100,000. On the basis of the above

basic concepts, arbitrary sub-classifications can be established, for example, Class 1000 and Class 50,000 to suit the convenience; and it will be more rational and economical to produce a large variety of products in the environments of these arbitrary classes so long the quality remains unaffected by the extent of dust control guaranteed in these arbitrary classes.

In other words, the above consideration raises the necessity of determining the optimum clean room class for each product, and once this is determined, the products can be produced most economically. This aspect constituted one of the main themes in the present tour of the delegation.

The greatest gain the delegation made during this trip was to visit the clean rooms of both state and private establishments, (for example, the clean room of the Oak Ridge National Atomic Energy Laboratory of the NASA where state projects are being carried out, and that of the Univac Co. where the parts of computers are manufactured for general use) and get a first-hand knowledge of the management of the clean rooms catering to the two different types of demands, viz., the state demands and the private demand.

The giant laminar flow type clean room which the NASA has erected for repair and inspection of the spacecraft seems to be an impossible proposition for Japan. Even in the NASA, the conventional type clean room used for the fabrication and inspection of the fuel section of the rocket is of a type which can be conceived easily for the private enterprises for assembling the engines and the hydraulic systems.

The clean room research programs of both the Oak Ridge National Atomic Energy Laboratory and the Sandia Laboratories under the direct jurisdiction of the US Atomic Energy Commission cover the theoretical as well as the practical aspects, and now-a-days, the emphasis seems to have shifted to the question of bioclean room required for planetary quarantine.

Again, while discussing the management of the clean room in the computer parts plant of the Univac Co. we were told that they were literally implementing the trial and error method for

each and every part in order to ascertain the minimum clean room conditions required for their manufacture. In fact, there were stringent regulations regarding clean room apparels and air shower for the clean room we visited at the time it was erected, but later on through experience it was found that the use of the clean room apparels and the air shower could be eliminated by using the clean benches and the clean transportation boxes, and hence the regulations have since been relaxed allowing the people working inside to use ordinary dress. This step has resulted in vast improvement in the working efficiency.

Again, the Boeing Co. has established its own clean room specifications, which set up the manufacturing environment for the respective parts. One of the Boeing laboratories we saw corresponded to the clean room Class S of the Boeing Co. specification and we were told that this was slightly inferior to the Class 100,000 laid down in the Federal Standard.

According to a number of literature data, the NASA and the manufacturer carry out a joint study of the most rational class of room suited for manufacturing each of the parts intended for the NASA and of the cost factor involved; and in this respect all efforts are made by the NASA officials to effect economy second to none of the private enterprises although the NASA is a purely government agency.

In this way, the Mission was able to see the diffusion of the concept of clean room in the world of industry, and at the same time got a first hand knowledge of the high esteem the private enterprises have for the Federal Standard, while manipulating freely with the standard, sometimes falling just short of violation of the procedure and the spirit of the clean room. As against the hardware which is called as the Federal Standard, there are softwares which are used in the clean room for different purposes, and in this respect the vast gap that separates the USA from Japan was noticed very vividly. The present visit was very useful because it was possible to get an idea of the line in which the research on clean rooms is going to develop in future, besides getting a unique opportunity to see a large number of clean rooms.

SUM UP

The participation of the people belonging to the electronics and precision instrument industries, people actually engaged in designing and fabricating these, as well as of the filter makers was found to be very rewarding, as it was possible to exchange views, each member expressing his vi ws from the angle of his own specialization.

In the end, it is earnestly hoped that the members of the mission will share the experience tney have gained from this trip, and exchange views with the people working in the related fields for bringing about an improvement in the technique of air cleaning and contributing to the development of the air cleaning industry in general.

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6. LIST OF DOCUMENTS COLLECTED BY THE MISSION

1. Clean Air is a Breeze - A 16mm Talkie Technicolor Film, by Sandia Laboratories.

2. Washing the Clean Room Apparels - A 16mm Talkie Technicolor Film, by SPACE Co.

3. Contamination Control Handbook by Sandia Laboratories.

4. Design, Construction and Testing of High-Efficiency Air Filtration Systems for Nuclear Application by C. A. Burchsted and A. B. Fuller.

5. Standards and Guidelines for the Design and Operation of Clean Rooms and Clean Work Stations (TO-00-25-203).

6. Sizing and Counting Particulate Contaminant in and on Clean Room Garments (ASTM F-56-65).

7. Tentative Standard for HEPA Filters (AACC-CS-IT).

8. Tentative Standard for Laminar Flow Clean Air Devices (AACC-CS-2T).

9. Principles of Operation of the Vacuum Probe Microbiological Sampler (Sandia Laboratories).

10. Design Requirements for Laminar Air Flow Clean Rooms and Devices (Sandia Laboratories).

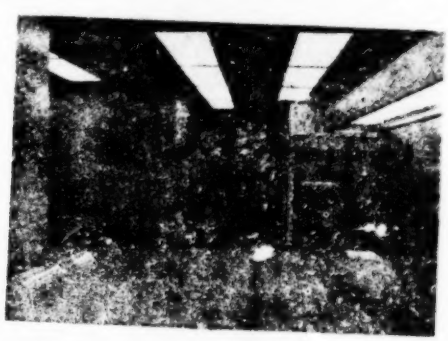
11. Guidelines and Procedures for Operation of NASA unmanned Spacecraft Assembly and Checkout Clean Room Facilities Hanger S. Building AE, Building AO Cape Kennedy Air Force Station, Florida.

DOCUMENTS COLLECTED BY THE MISSION

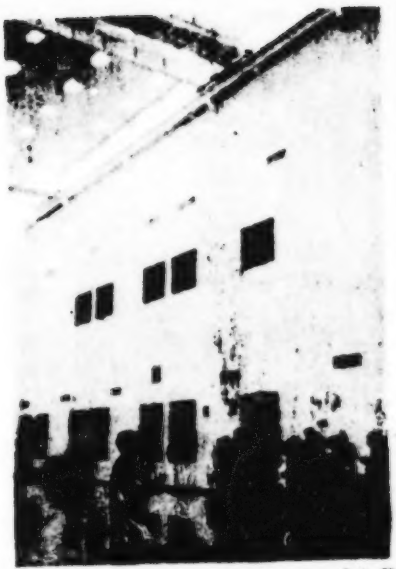
12. Design a Modern Metrology Laboratory (by Boeing).
13. AAF Composite Catalogs.
14. Angelica Catalogs.
15. Royco Catalogs.
16. ATI Catalogs.

7. PHOTOGRAPHS

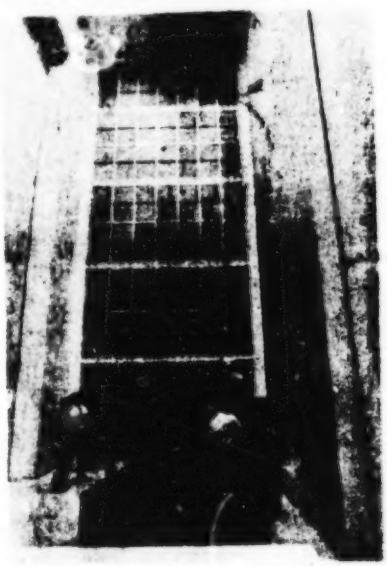
Parts inspection and washing plant, J.F.K. Space Center



Parts inspection and washing plant, Clean Room (Conventional), J.F.K. Space Center



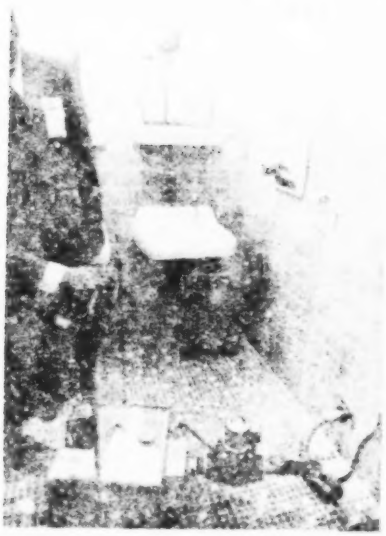
High Bay Clean Room inside the AO Building



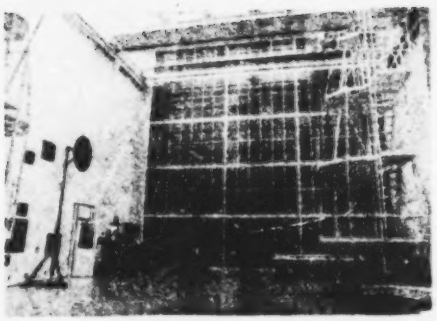
Reserve Clean Room in the Flight Handling Plant (Laminar air flow), J.F.K. Space Center

Reproduced from
best available copy.

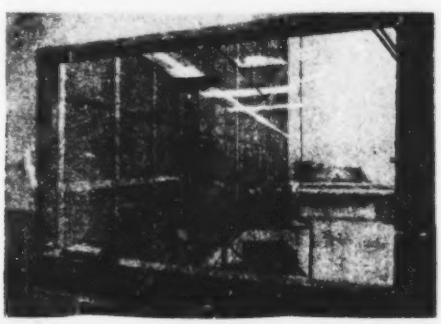
Research Clean Room (Laminar air flow) in the Flight Handling Plant. Blast plenum chamber, protective filter has been provided to the HEPA filter, J. F. K. Space Center



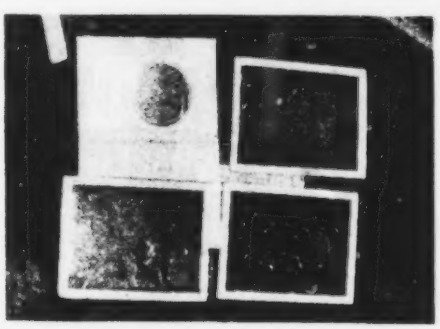
Front room in the Flight Handling Plant, J. F. K. Space Center



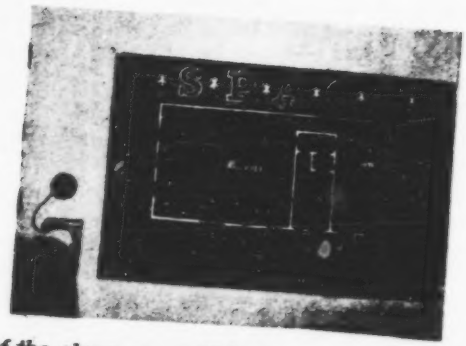
Main working room in the Flight Handling Plant (laminar air flow), J.F.K. Space Center.



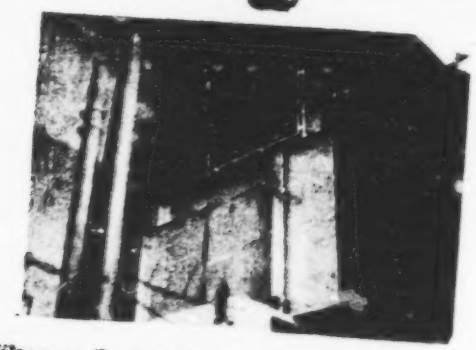
Flight Handling Factory: view of the main working room from the monitoring room, J.F.K. Space Center



Photographs obtained with the dust content investigation microscope, SPACE Co. (reference)

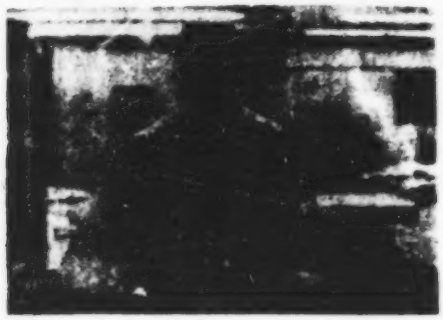


Plan of the clean room SPACE Co. (reference)



HEPA filter on the top of the dryer (the filter seen in the photograph is the prefilter, SPACE Co (reference)

Folding and packing of the apparels, SPACE Co. (reference)



Dust content inspection, SPACE Co. (reference)